T.O. 33A1-6-63-1

TECHNICAL MANUAL

INSTRUCTIONS AND PARTS BREAKDOWN

IMPEDANCE BRIDGE MODEL 250DA

(ELECTRO-SCIENTIFIC INDUSTRIES, INC.)

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OPERATING ROUTINES AND INTERVALS

2-5 There are no operating routines for the impedance bridge.

OPERATING PROCEDURES

Operating Controls and Indicators

2-6 Operating controls and indicators of the impedance bridge are illustrated in Figure 2-1; their functions are explained in Table III.

Preliminary Adjustments and Control Settings

2-7 Make sure the power switch is at OFF and no connections are made to the impedance bridge when the power cord is connected. Other preliminary adjustments and control settings do not apply to every procedure; therefore, they are included where applicable in the step-by-step procedures.

Starting

2-8 The impedance bridge is ready for use when the power cord is connected to a 110-120 volt, 50-400 cycle convenience outlet. After completion of the preliminary connections, adjustments, and control settings for the measurement to be made, turn the AMP control clockwise; the power indicator lamp should light (red), indicating power is on.

2-9 DC measurements may be made immediately. Wait until the AC null indicator lights (green) before starting AC measurements.

Measuring Resistance

2-10 *Resistance Measurements With DC Input to Bridge.*—Make the following preliminary control settings (Figure 2-2):

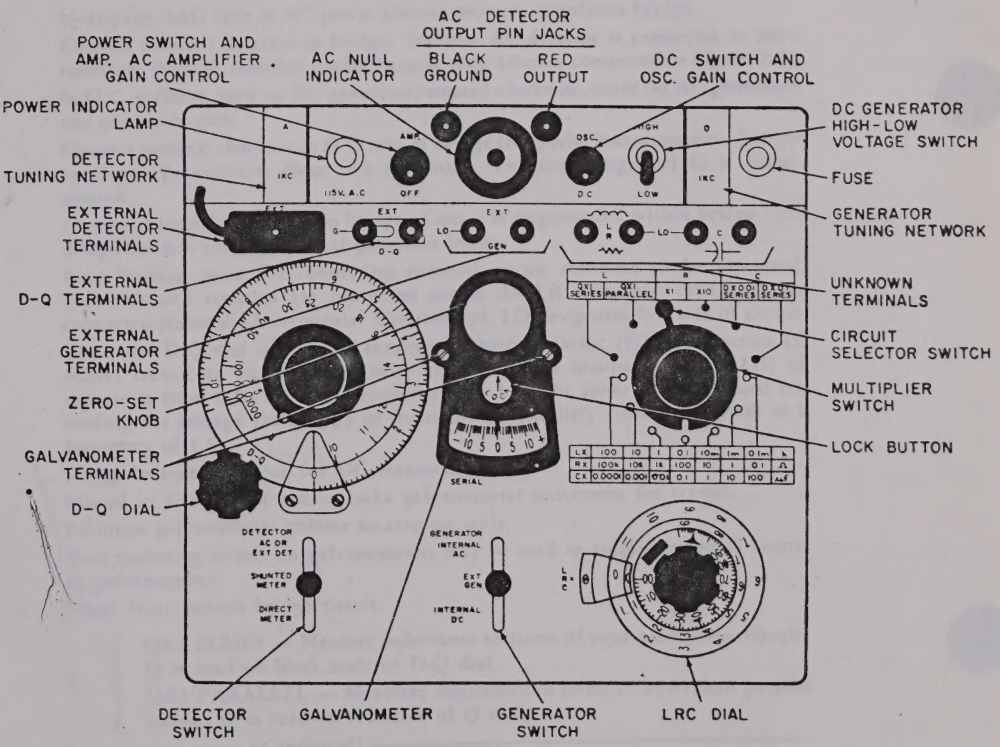


Figure 2-1. Impedance Bridge, Controls and Indicators

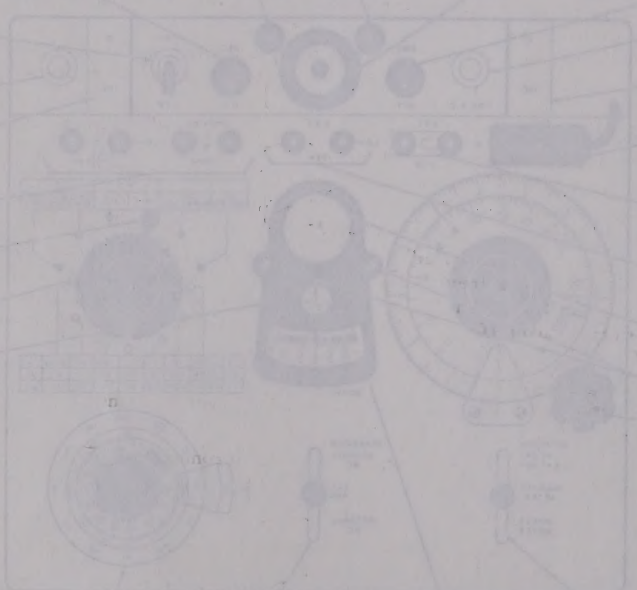


TABLE III

IMPEDANCE BRIDGE CONTROLS AND INDICATORS

Control or Indicator	*Function*
Detector tuning network	Tunes AC detector to 1000 cycles. May be removed for untuned detector.
AMP AC amplifier gain control	Sensitivity control for AC detector.
Power switch (ganged) with AMP AC amplifier gain control)	Turns on high and low DC power supplies.
Power indicator lamp	Lights (red) when power is on.
AC detector output pin jacks	For connecting external indicator to AC detector output terminals; black jack is ground, red jack is output.
AC null indicator	Null-balance indicator for AC measurements. Null is indicated by maximum opening of the eye.
DC generator HIGH-LOW voltage switch	For selecting DC bridge voltage for resistance measurements: HIGH — Use for resistance above 1,000 ohms. LOW — Use for resistance below 100 ohms.
Generator tuning network	Fixes AC generator frequency at 1000 cycles.
Fuse	½-ampere, 3AG fuse in AC power circuit; protects impedance bridge.
EXT DET terminals (binding posts)	Connect external detector to bridge. Internal AC detector is connected to these terminals through shielded double-banana plug (shown connected in Figure 2-1).
D.C. switch and OSC. gain control	In D.C. position, turn on DC generator; rotated clockwise, turns on AC generator, and adjusts its gain.
EXT D-Q terminals (binding posts)	Connect external elements to D-Q arm of bridge for special measurements. Jumper bar normally connects these two terminals. The one designated G is chassis ground.
EXT GEN terminals (binding posts)	Connect external generator to bridge. Circuit is ungrounded within bridge. LO designates low side of external generator input.
Unknown terminals, LR and C (binding posts)	Four binding posts for connecting external circuit elements to be measured. Inductors and resistors are connected across the LR terminals; capacitors are connected across the C terminals. Ungrounded, LO designates low side of circuit.
D-Q dials	The outer D-Q dial is used for reading the storage factor (Q) of inductors (L series) from 0 to 10.5 at a frequency of 1 kc or the dissipation factor (D) of capacitors from 0 to 1.05 at a frequency of 1 kc. The inner Q dial is used for reading the storage factor (Q) of inductors (L parallel) from 10 to 1000 at a frequency of 1 kc.
Galvanometer	Bridge-balance indicator for DC measurements.
LOCK button	Moved in direction of arrow, locks galvanometer movement for transit.
Zero-set knob	Positions galvanometer pointer to zero on scale.
Galvanometer terminals	Two mounting screws on galvanometer; may be used to connect external circuit to galvanometer.
Circuit selector switch	Metal lever; selects bridge circuit: L { QX1 SERIES — Measure inductance in terms of equivalent series circuit; Q as read on black scale of D-Q dial. QX1 PARALLEL — Measures inductance in terms of equivalent parallel circuit; Q as read on red scale of Q dial.

(Continued)

IMPEDANCE BRIDGE CONTROLS AND INDICATORS

Control or Indicator	Function
Detector tuning	Tunes AC detector to 1000 cycles. May be removed for manual detector
Meters	
AC/DC amplifier	Sensitivity control for AC detector
gain control	
Power switch	Turns on high and low DC power supplies.
(pumped) with	
AC/DC amplifier	
gain control)	
Power indicator	
lamp	Lights (red) when power is on.
AC detector output	For connecting external indicator to AC detector output terminals; black jack is
pin jacks	ground, red jack is output.
AC null indicator	Null-balance indicator for AC measurements. Null is indicated by maximum
	opening of the eye.
DC galvanometer	For selecting DC bridge voltage for resistance measurements:
HIGH-LOW	HIGH — Use for resistance above 1000 ohms
voltage switch	LOW — Use for resistance below 100 ohms
Detector tuning	Tunes AC detector to 1000 cycles.
Meters	
Type	
EXT DET terminals	
(binding posts)	
DET. ratio and	
DET. gain control	
EXT D-Q terminals	
(binding posts)	
EXT GEN terminals	
(binding posts)	
Unknown terminals	
LP and C	
(binding posts)	
D-Q dials	
Gain-compensator	
LOCK button	
Generator knob	
Galvanometer	
terminals	
Detail selector	
switch	
D	D-Q SERIES — Measures inductance in terms of equivalent series circuit Q as read on black scale of D-Q dial.
	D-Q PARALLEL — Measures inductance in terms of equivalent parallel circuit Q as read on red scale of Q dial.

(Continued)

TABLE III. IMPEDANCE BRIDGE CONTROLS AND INDICATORS (Continued)

Control or Indicator	*Function*
R	X1 — Resistance measured is product of LRC dial and multiplier-switch settings. X10 — Resistance measured in ten times product of LRC dial and multiplier-switch settings.
C	Position used during capacitance measurements. The two positions D X 0.01 SERIES and D X 0.1 SERIES do not affect capacitance values measured, but do affect dissipation (D) factors measured. In the D X 0.01 SERIES position, D is 0.01 times reading of D-Q dial times frequency in kc. In the D X 0.1 SERIES position, D is 0.1 times reading of D-Q dial times frequency in kc.
Multiplier switch	Black knob concentric with circuit selector switch. Pointer indicates value of multiplier and units used: LX — 100, 10, 1, and 0.1 henries and 10, 1, and 0.1 millihenries. RX — 100, 10, and 1 kilohms and 100, 10, 1, and 0.1 ohms. CX — 0.0001, 0.001, 0.01, 1, 10, and 100 microfarads.
DETECTOR switch	Selects detector to be used: AC or EXT DET — AC internal detector or external detector or external detector connected via EXT DET terminals to detector arm of the bridge. SHUNTED METER — Galvanometer with protective shunt connected to detector arm of bridge. DIRECT METER — Galvanometer without protective shunt connected to detector arm of bridge.
GENERATOR switch	Selects generator or voltage source to be used: INTERNAL AC — Internal AC generator connected to bridge. EXT GEN — External generator connected via EXT GEN terminals to bridge. INTERNAL DC — Internal DC generator connected to bridge.
LRC dial	Three concentric dials read value of unknown inductance, resistance, or capacitance being measured. Measured value is product of dial reading and multiplier reading. For resistance, this product is also multiplied by circuit selector switch position.

WARNING

Ensure that AMP control is completely counter clockwise (power off) and power indicator lamp is off when connections are made to unknown terminals. Up to 300 volts may appear at these terminals when power is on.

a. Connect unknown resistor to LR terminals. Be sure to make good contact with the terminals.

b. Set DC generator switch to LOW. This applies about 10 volts to bridge.

c. Unlock galvanometer with LOCK button. Zero the galvanometer with zero-set knob.

d. Turn AMP control clockwise; power indicator lamp will go on indicating power is turned on.

e. Turn OSC control to D.C. The green fluorescent screen on AC null indicator will go out.

f. Set circuit selector switch to R X1 for resistances of up to 1.2 megohms; to R X10 for resistances of between 1.2 and 12 megohms.

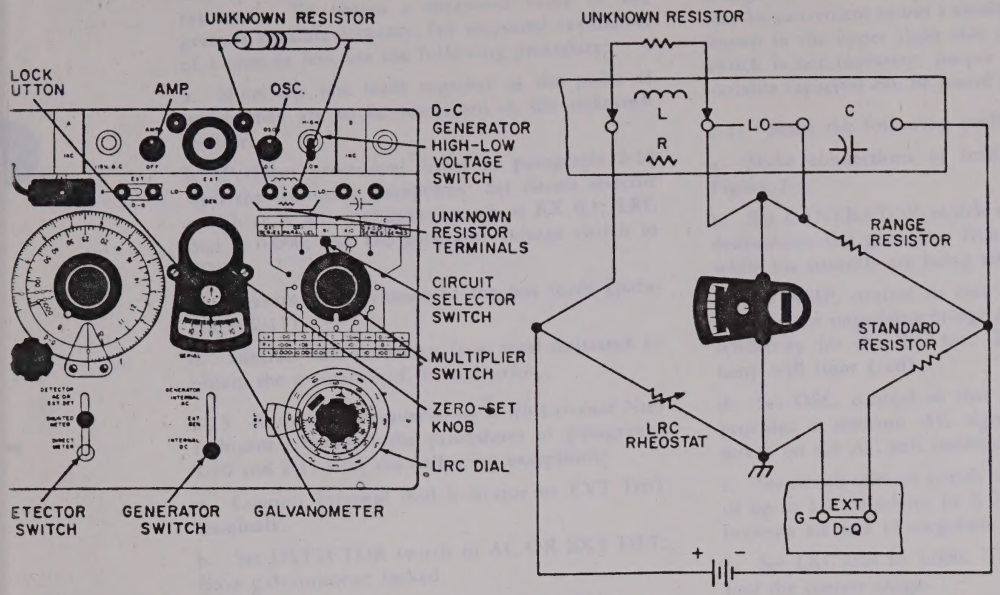


Figure 2-2. Resistance Measurement With DC Applied to Bridge

g. Set LRC dial to 3.000; this facilitates finding the correct range (outer dial on 3, middle dial on 0, inner dial on 00).

h. Set DETECTOR switch to SHUNTED METER. This cuts down the meter sensitivity and makes it easier to find a rough null.

i. Set GENERATOR switch to INTERNAL DC. This connects DC generator to the bridge.

2-11 Measure the resistance as follows:

a. Adjust multiplier switch for minimum galvonometer deflection. As the switch is moved through its range, the galvanometer deflection shifts from one side to the other. If deflection is off scale on each side, set the switch at the position that seems to give the least "kick" to the pointer.

b. Adjust LRC dial for null. As null is approached, set DETECTOR switch to DIRECT METER to increase sensitivity.

c. If the LRC-dial reading is less than 1.200, turn the multiplier switch to the next lower setting and readjust the LRC dial for null. This takes advantage of the increased resolution near the full scale of the dial.

d. For resistance greater than 10,000 ohms, set the DC generator voltage switch to HIGH to increase sensitivity.

WARNING

Up to 300 volts will be present across the LR terminals when the DC generator voltage switch is set to HIGH.

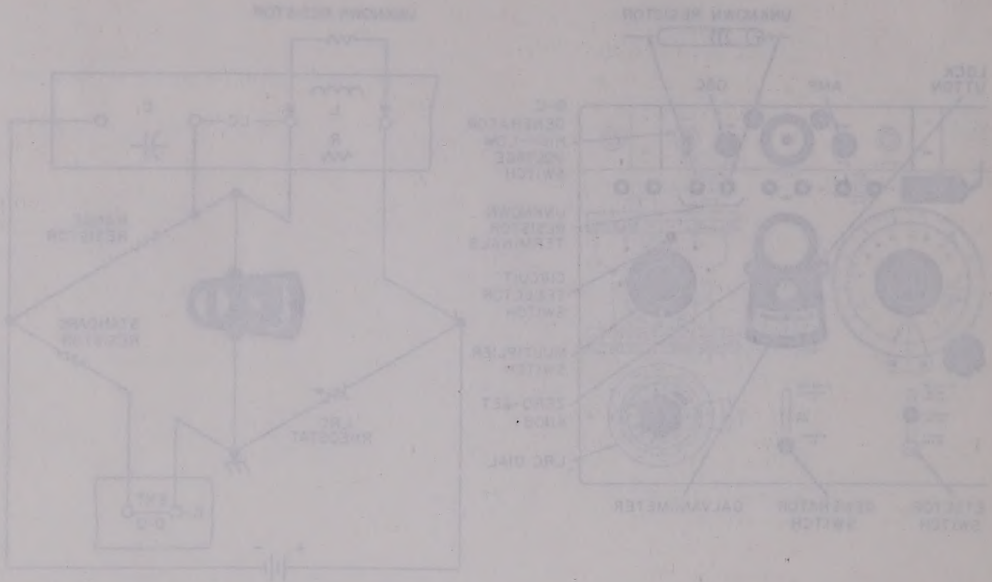
e. The measured resistance is the product of the following control settings: multiplier switch, circuit-selector switch, and LRC dial.

f. If measured resistance is under 1 ohm, see paragraph 2-12 and perform procedures when applicable.

g. Before disconnecting the measured resistor, set the GENERATOR switch to EXT GEN; the DETECTOR switch at SHUNTED METER, and the DC generator voltage switch to LOW. This disconnects the generator, protects the galvanometer, and removes high voltage from the bridge.

h. Before leaving the bridge, lock the galvanometer to protect it from mechanical damage and set the AMP. switch to OFF to turn off the power supply.

2-12 *Correction for Lead Resistance.* — At low values of unknown resistance, test-lead resistance



may be a significant proportion of the measured resistance. To obtain a measured value of the greatest possible accuracy, for measured resistances of 1 ohm or less, use the following procedure:

a. Short the test leads together at the point at which they are to be connected to the unknown resistor.

b. Perform procedures listed in paragraph 2-10 with the following exceptions: Set circuit selector switch at R X1; multiplier switch at RX 0.1; LRC dial at 0.000; and DC generator voltage switch to LOW.

c. Measure the resistance of the test leads (paragraph 2-11).

d. Subtract lead resistance from total resistance to obtain the resistance of the unknown.

2-13 *Resistance Measurements With External Null Indicator.*—Perform the procedures of paragraphs 2-10 and 2-11 with the following exceptions:

a. Connect external null indicator to EXT DET terminals.

b. Set DETECTOR switch to AC OR EXT DET; leave galvanometer locked.

c. Measure the resistance (paragraph 2-11).

d. Leave DETECTOR switch at AC OR EXT DET. If sensitivity control of external null indicator is adjustable, increase sensitivity toward maximum as null is approached. Always obtain final null when detector is at greatest possible sensitivity.

2-14 An external electronic null indicator may be affected by AC hum and ripple in the power supply of the internal generator. If hum or ripple masks the null, set the AMP. control to OFF and connect an external battery to the EXT GEN terminals. Use a protective resistor greater than $(\frac{1}{4})$ (battery voltage)^2 ohms in series with the battery. When an external battery is used, set GENERATOR switch to EXT GEN to connect power to the bridge circuit.

2-15 *Resistance Measurements With AC Input to Bridge.*—For greatest accuracy, always measure resistors with DC. The accuracy of AC measurement for resistors with low reactance is 0.3 per cent for 1 kilocycle and below, over the range from 1 ohm to 1 megohm. The procedure set forth here should be used when measuring resistance of a resistor with capacitance in parallel or a resistor with inductance in series.

2-16 Figure 2-3 shows the test connections. The connections indicated for the phase-correction capacitor compensate for series inductance or parallel capacitance. It is impossible to separate the correction for the unknown from that for the rest of the bridge circuit. If the phase correction is small, it may be convenient to use a small, fixed capacitor, as shown in the upper right side of Figure 2-3. The switch is not necessary; proper connection for the variable capacitor can be found by trial.

2-17 Make the following preliminary settings:

a. Make connections to bridge as indicated in Figure 2-3.

b. Set GENERATOR switch to EXT GEN. This disconnects the generator from the bridge circuit while the controls are being set up.

c. Set AMP, control so that the dot is up. This turns on the impedance bridge and provides medium sensitivity for the detector. The power indicator lamp will light (red).

d. Set OSC. control so that the dot is up. This provides a medium AC signal. The fluorescent screen on the AC null indicator will light (green).

e. Set circuit selector switch to R X1 for resistances of up to 1.2 megohms; to R X10 for resistances of between 1.2 and 12 megohms.

f. Set LRC dial to 3.000. This makes it easier to find the correct range.

g. Set DETECTOR switch to AC OR EXT DET. This connects the AC detector to the bridge circuit.

NOTE

Ensure that detector network plug (shielded banana plug) is connected to EXT DET terminals.

h. Set GENERATOR switch to INTERNAL AC.

2-18 Measure the resistance as follows:

a. Adjust multiplier switch for widest possible shadow on the AC null indicator. The shadow widens and narrows as the multiplier switch is turned through its range.

b. Adjust the AMP. and OSC. controls as required. If a narrow shadow does not change in width as the multiplier switch is turned through two or more positions, the bridge is not sensitive enough. Turn the AMP. or OSC. control clockwise until it is easy to tell the proper multiplier switch setting. If a wide shadow does not change, the bridge is too sensitive. Turn the AMP. or OSC. control counterclockwise until it is easy to tell the proper multiplier switch setting.

c. Adjust LRC dial for the widest and sharpest possible shadow on the AC null indicator. As null is approached, turn the AMP. control, OSC. control, or both, clockwise to increase sensitivity.

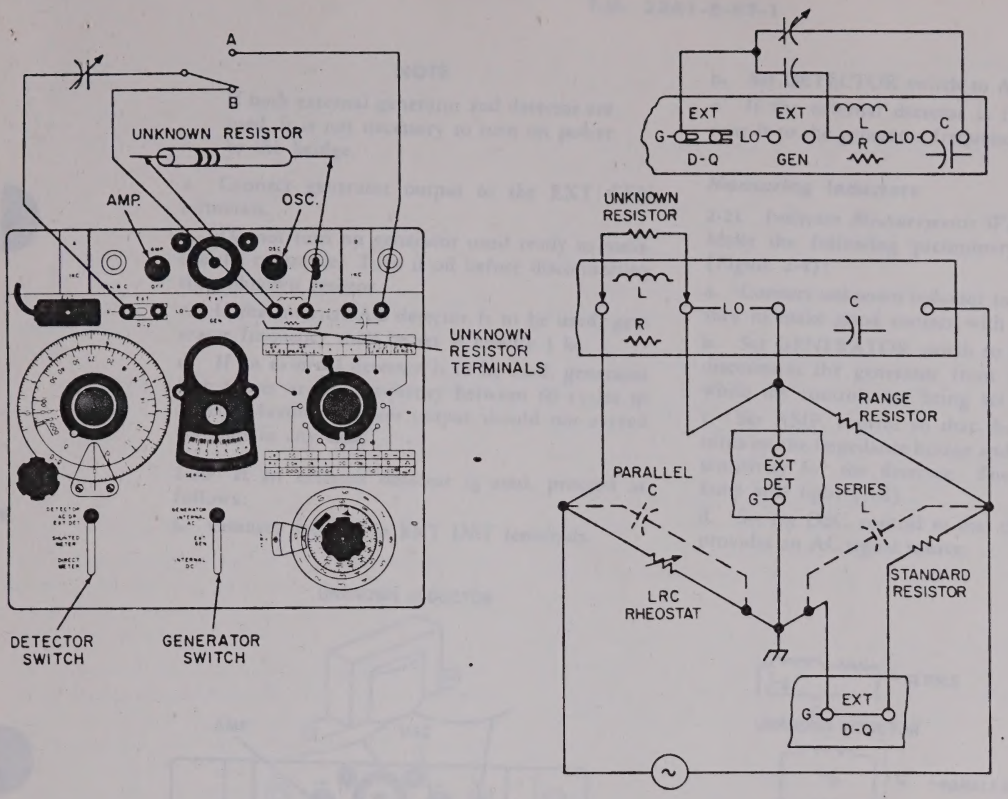


Figure 2-3. Resistance Measurement With AC Applied to Bridge

d. If the LRC dial indication is less than 1.200, turn the multiplier switch to the next lower setting and readjust the LRC dial for null. This takes advantage of the increased resolution near the full scale of the dial.

e. At balance, the AC null indicator should show a wide shadow with sharp, bright boundaries. If a proper null cannot usually be obtained by the procedure just described, compensation may be necessary for phase shifts. The shadow may remain narrow or wide with fuzzy boundaries because of uncompensated phase shift.

f. If uncompensated phase shift is present, connect variable capacitor as shown in position A of Figure 2-3, and try to obtain a null with the capacitor and the LRC dial.

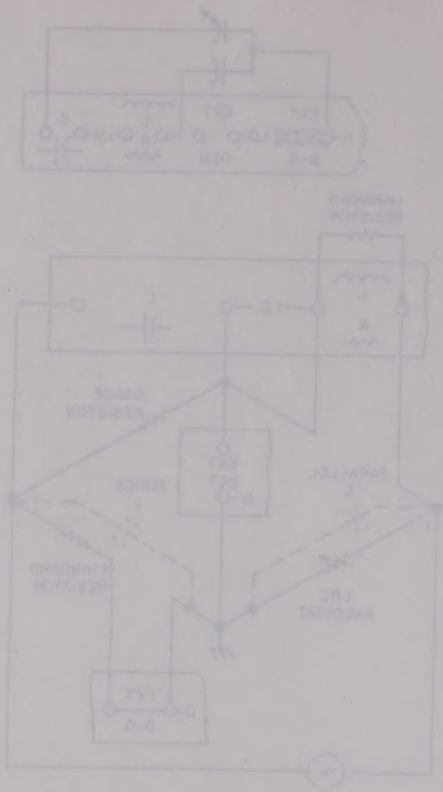
g. If null is not obtained, reconnect capacitor as shown in position B of Figure 2-3 and try again. A null should be obtained with one of these connections. However, null balance is not possible if a nonlinear element is being measured, because the bridge will not be in balance at all parts of the cycle.

h. The resistance will be the product of the following control settings: multiplier switch, circuit selector switch, and LRC dial. Accuracy will be 0.3 per cent or better for resistors between 1 ohm and 1 megohm at a frequency of 1 kc or less.

i. Before disconnecting the resistor, set GENERATOR switch to EXT GEN. This disconnects the generators while the resistor is being removed.

j. Before leaving the bridge, set AMP. control to OFF to turn off the power supply.

2-19 *Resistance Measurements With AC Applied to Bridge External Detector and/or Generator.*— This procedure is basically the same as that described in paragraphs 2-15 through 2-18. If an external generator is used, proceed as follows:



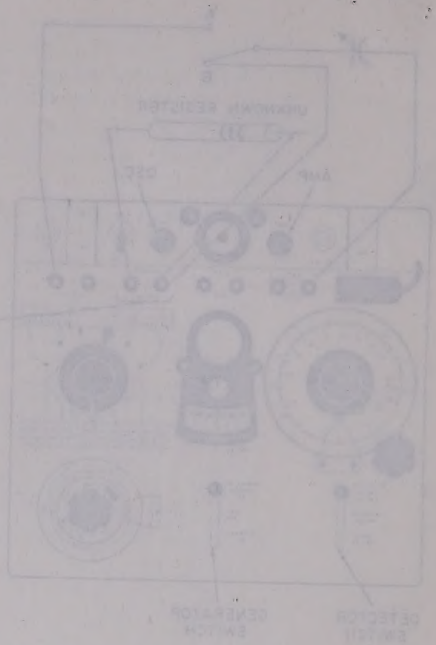


Figure 2-3. Resistance Measurement With AC Applied to Bridge

NOTE

If both external generator and detector are used, it is not necessary to turn on power to the bridge.

a. Connect generator output to the EXT GEN terminals.

b. Do not turn on generator until ready to measure the resistance. Turn it off before disconnecting the unknown resistor.

c. If the internal AC detector is to be used, generator frequency shall be set at exactly 1 kc.

d. If an external detector is to be used, generator may be set at any frequency between 60 cycles to 10 kc. Maximum power output should not exceed 0.5 watt in any case.

2-20 If an external detector is used, proceed as follows:

a. Connect detector to EXT DET terminals.

b. Set DETECTOR switch to AC OR EXT. DET.

c. If the external detector is frequency selective, tune it to the generator frequency.

Measuring Inductors

2-21 *Inductor Measurements With AC Applied.*— Make the following preliminary control settings (Figure 2-4):

a. Connect unknown inductor to LR terminals. Be sure to make good contact with the terminals.

b. Set GENERATOR switch to EXT. GEN. This disconnects the generator from the bridge circuit while the controls are being set up.

c. Set AMP. control so that the dot is up. This turns on the impedance bridge and provides medium sensitivity for the detector. The power indicator lamp will light (red).

d. Set the OSC. control so that the dot is up. This provides an AC signal source.

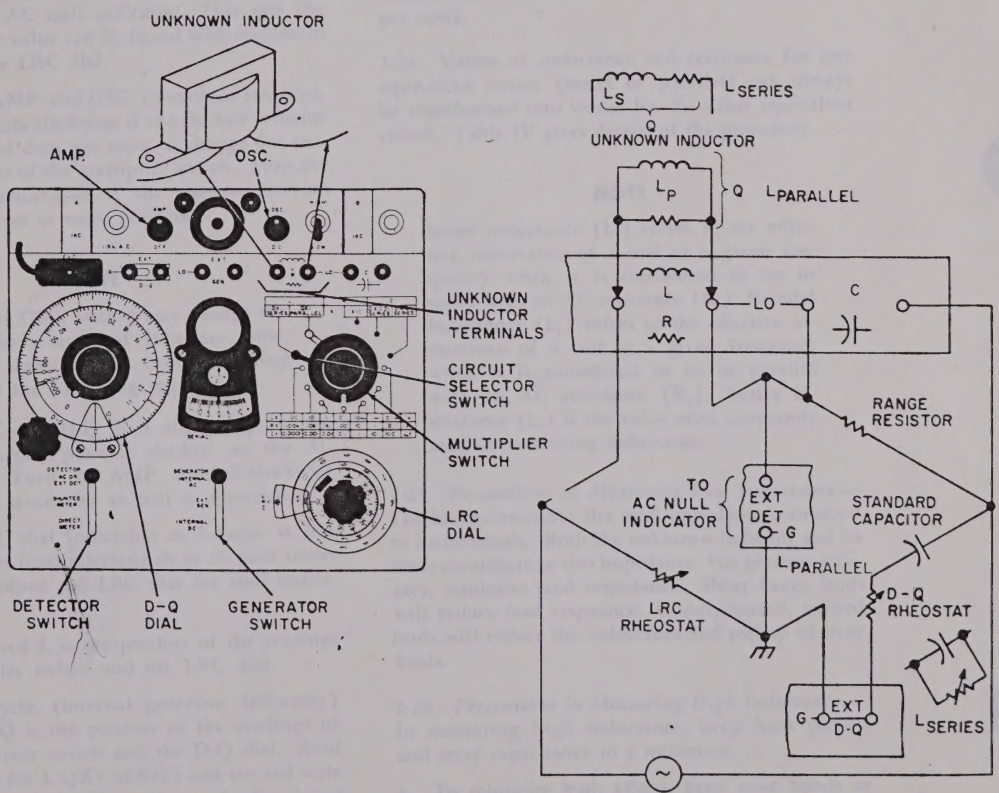
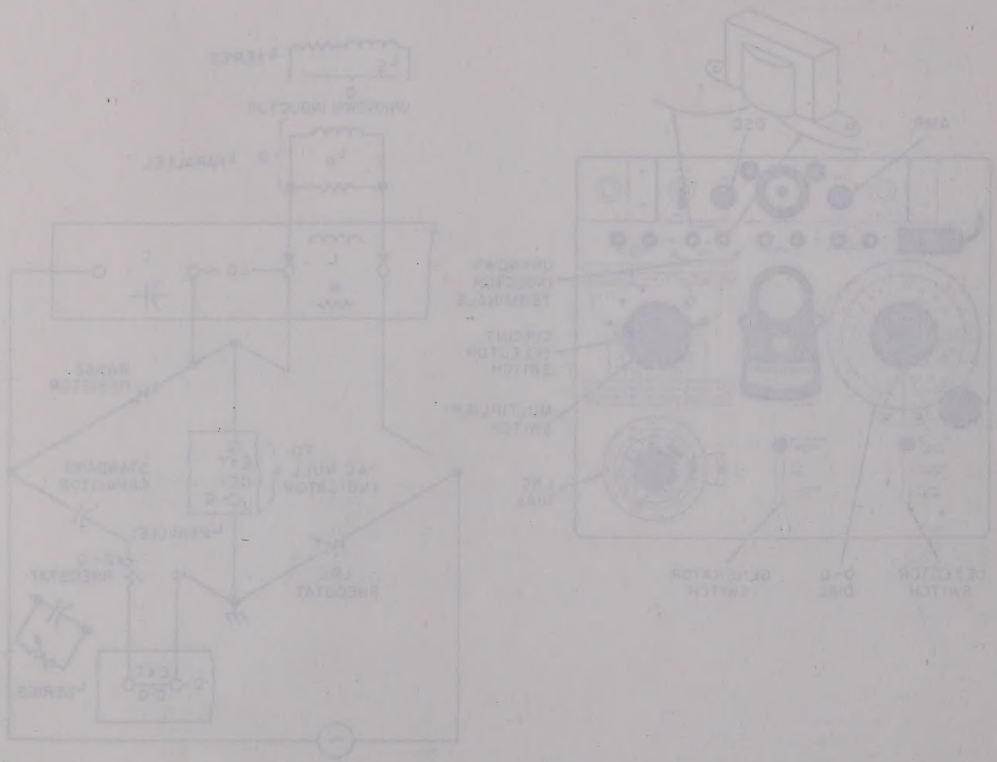


Figure 2-4. Inductor Measurements



e. Set circuit selector switch to the appropriate L circuit. Use position QX1 SERIES for storage (Q) factors less than 10; use position QX1 PARALLEL for storage (Q) factors greater than 10.

NOTE

Either L position may be used for measuring inductance solely.

f. Set LRC dial to 3.000; set D-Q dial to maximum. These settings facilitate finding the correct range.

g. Set DETECTOR switch to AC OR EXT DET: this connects the detector to the bridge.

h. Set GENERATOR switch to INTERNAL AC; this connects the generator to the bridge.

2-22 Measure the inductor as follows:

a. Adjust multiplier switch for the widest possible shadow on the AC null indicator. This sets the range so that the value can be found with maximum resolution on the LRC dial.

b. Adjust the AMP. and OSC. controls as required. Turn these controls clockwise if the shadow remains nearly closed and does not seem to change for two or more positions of the multiplier switch. Turn the controls counterclockwise if the shadow remains wide open for two or more positions.

NOTE

Altering the OSC. setting may change the measured inductance of iron-core coils. Keep the same OSC. control setting throughout the following steps.

c. Adjust LRC and D-Q dials alternately for the widest and sharpest possible shadow on the AC null indicator. Turn the AMP. control clockwise to increase the sensitivity as null is approached.

d. If the LRC dial indication at balance is less than 1.200, turn multiplier switch to its next lower setting and readjust the LRC dial for null indication.

e. The measured L is the product of the readings of the multiplier switch and the LRC dial.

f. At 1 kilocycle, (internal generator frequency) the measured Q is the product of the readings of the circuit selector switch and the D-Q dial. Read the black scale for L QX1 SERIES and the red scale for L QX1 PARALLEL settings of the circuit selector switch.

g. For Q SERIES at other frequencies (etxernal generator) multiply this value by frequency in kilocycles.

h. For Q PARALLEL at other frequencies divide this value by frequency in kilocycles.

i. Before disconnecting the inductor, set GENERATOR switch at EXT GEN. This disconnects the generator while the inductor is being removed.

j. Before leaving the bridge, set AMP. control to OFF to turn off the power supply.

2-23 *Series and Parallel Inductance.*—The impedance bridge measures a simple equivalent circuit for the impedance connected to its terminals. The equivalent series circuit is an inductance and resistance connected in series; the equivalent parallel circuit is an inductance and resistance connected in parallel. The phase and magnitude of the resulting impedance are identical for both circuits. However, for values of Q less than 100, the series and parallel inductances differ measurably (by more than 0.01 per cent).

2-24 Values of inductance and resistance for one equivalent circuit (series or parallel) can always be transformed into values for the other equivalent circuit. Table IV gives details of the procedure.

NOTE

Series inductance (L_s) refers to the effective inductance of a coil at a given frequency when it is considered to be in series with an AC resistance (R_s). Parallel inductance (L_p) refers to the effective inductance of a coil at a given frequency when it is considered to be in parallel with an AC resistance (R_p). Series inductance (L_s) is the value most commonly used in measuring inductance.

2-25 *Precautions in Measuring Low Inductance.*—The bridge measures the total impedance connected to its terminals. Both the unknown inductor and its leads contribute to this impedance. For greatest accuracy, minimize lead impedance. Short heavy leads will reduce lead resistance. Closely-spaced, twisted leads will reduce the inductance and pickup of stray fields.

2-26 *Precautions in Measuring High Inductance.*—In measuring high inductance, keep hum pickup and stray capacitance to a minimum.

a. To minimize both effects, keep your hands as far as possiblbe from the inductor being measured.

TABLE IV
CIRCUIT RELATIONSHIPS IN EQUIVALENT SERIES AND PARALLEL INDUCTANCE CIRCUITS

Series Inductance L_s	*Parallel Inductance L_p*
L_s = (multiplier switch setting) × (LRC dial reading)	L_p = (multiplier switch setting) × (LRC dial reading)
Q = (circuit selector switch setting) × (D-Q dial reading) × (f_{kc})	Q = (circuit selector switch setting) × (D-Q dial reading) ÷ (f_{kc})
$D = \frac{1}{Q}$ Q and D in per unit	$D = \frac{1}{Q}$ D and Q in per unit
$R_s = \frac{1}{Q} \times 2\pi fL_s$ R_s in kilohms	$R_p = Q \times 2\pi fL_p$ R_p in kilohms
f in kc	f in kc
L_s in henries	L_p in henries
$2\pi = 6.28$	$2\pi = 6.28$

To calculate the equivalent parallel circuit:

The Q of the equivalent parallel circuit always equals the Q of the equivalent series circuit. The same is true of D.

$$L_p = \left(1 + \frac{1}{Q^2}\right) \times L_s$$

$$R_p = Q \times 2 \quad fL_p$$

To calculate the equivalent series circuit:

The Q of the equivalent series circuit always equals the Q of the equivalent parallel circuit. The same is true of D.

$$L_s = \frac{Q^2}{1 + Q^2} \times L_p$$

$$R_s = \frac{2\pi fL_s}{Q}$$

b. Keep leads as short and direct as possible. If extended leads are necessary, shield the lead from the LO terminal and connect a clip lead from the shield to the EXT D-Q terminal marked G. This places the capacitance between shield and inner conductor across the detector, where it cannot cause any error. The stray capacitance from the unshielded lead to ground appears in parallel with the LRC rheostat. Since resistance for big inductances is large, stray capacitance introduces very little phase shift.

c. Be careful to keep the inductor being measured away from stray magnetic fields.

2-27 The D and Q readings on the highest L range will be in error because of residual capacitance in the range resistor. Use the next lowest L range if accurate D or Q readings are needed. However, L readings on the highest range are accurate.

2-28 *Inductor Measurements — Use of External Generator and/or Detector.* — Procedures are the same as those for resistance measurement (paragraph 2-19).

2-29 *Measuring Alternating Current and Voltage in Unknown Inductor.*— Care must be taken in making these measurements to avoid false readings caused by loading effects of the measuring equipment. Paragraph 2-30 and 2-31 describe the proper measuring procedure.

2-30 *AC Voltage Measurement,*— Make the measurement as follows:

a. Before balancing the bridge (measuring the inductance), connect a high-impedance AC voltmeter as shown in Figure 2-5.

b. Measure the inductance (paragraphs 2-21 and 2-22).

c. Read the voltmeter. When the bridge is balanced, the voltage is equal to the AC voltage across the inductor, but the inductor has not been loaded by the voltmeter. The bridge readings, however, may be incorrect while the voltmeter is connected.

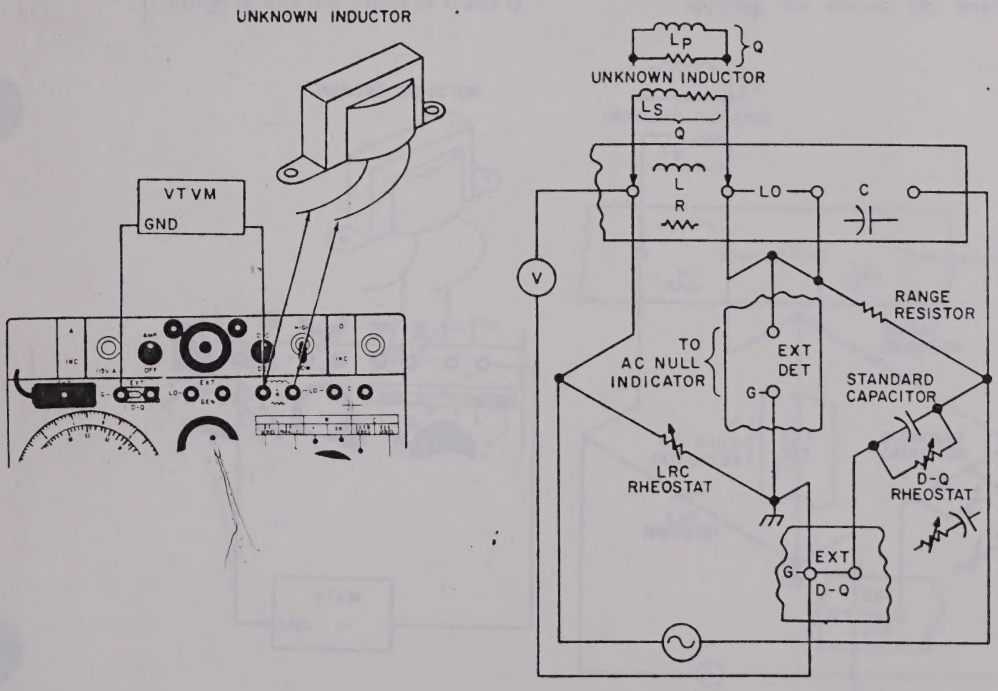
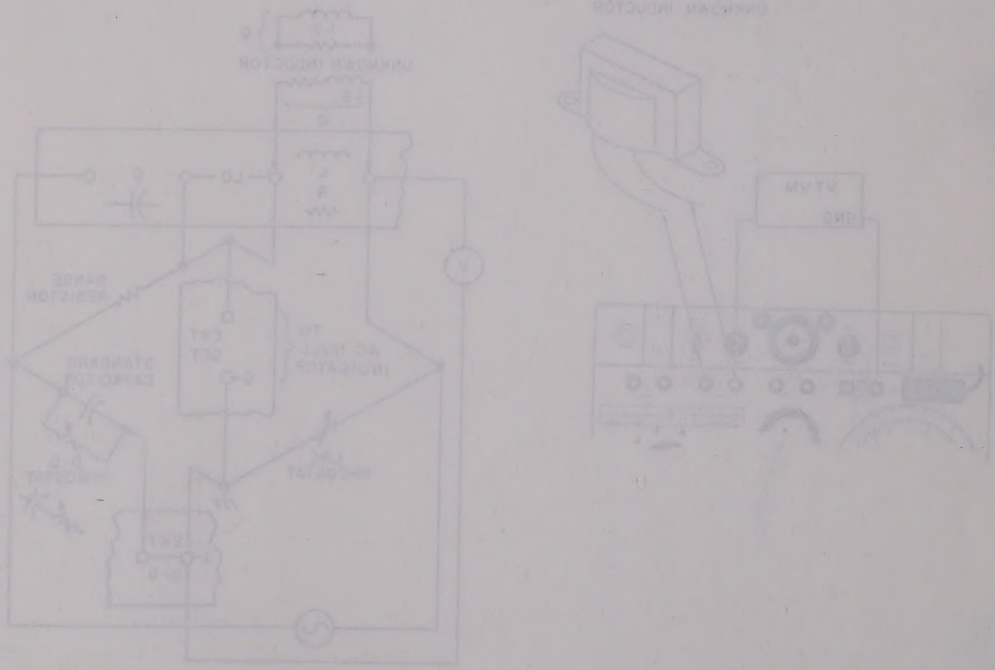


Figure 2-5. AC Voltage Measurement Across Unknown Inductor



d. Disconnect the voltmeter and rebalance the bridge to find true values of L and Q.

2-31 *Alternating Current Measurement.*— The AC voltage across the range resistor is proportional to the AC through the unknown inductor. (See Figure 2-6.) When the bridge is balanced, this voltage is equal to the voltage across the standard capacitor arm. Make the measurement as follows:

a. Before balancing bridge (measuring the inductance) connect a high impedance AC voltmeter as shown in Figure 2-6.

b. Measure the inductance (paragraphs 2-21 and 2-22).

c. Read the voltmeter. The AC current in milliamperes will be equal to the voltage read (in volts) times the multiplier M in Table V.

d. Disconnect the voltmeter and rebalance the bridge to find true values of L and Q.

TABLE V
AC MEASUREMENT FOR INDUCTANCE BRIDGE

Range	*Unknown Inductance*[a]	*M*
0.1 mh	0.1 uh to 1.2 mh	1000
1 mh	1 uh to 12 mh	100
10 mh	10 uh to 120 mh	10
0.1 h	100 uh to 1.2 h	1
1 h	1 mh to 12 h	0.1
10 h	10 mh to 120 h	0.01
100 h	100 mh to 1200 h	0.001

[a] Lower limit represents one dial division.

2-32 *Inductor Measurements With Superimposed DC.*— The measured inductance of iron-core inductors varies, depending upon the amount of DC flowing in the inductor.

NOTE

In some instances, the specifications for the inductor under test may require that DC be applied while measuring its inductance.

The following procedures provide two methods of applying the desired DC levels: DC supplied

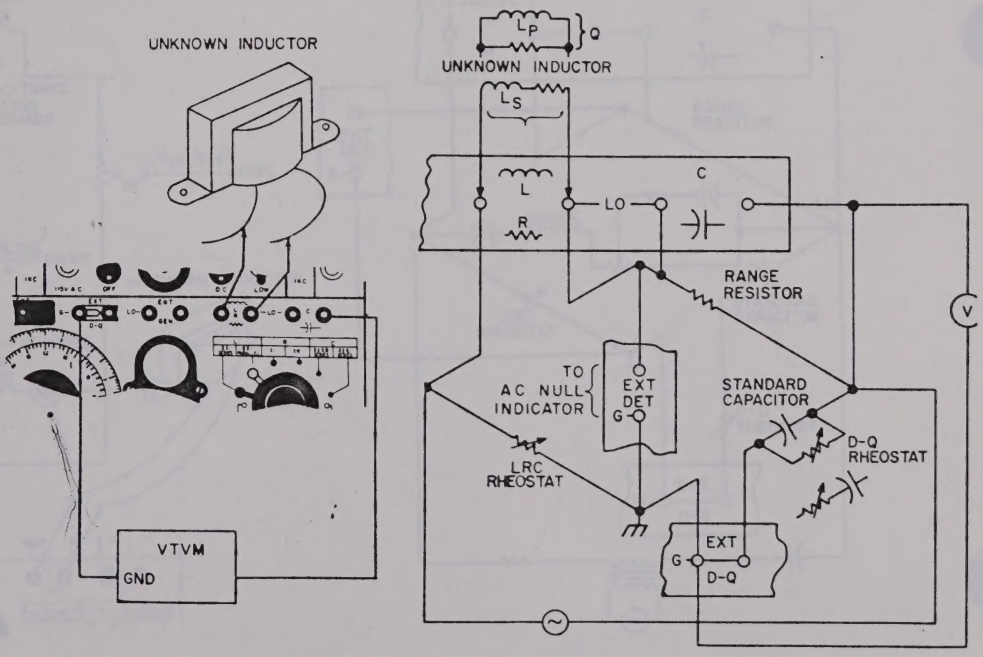
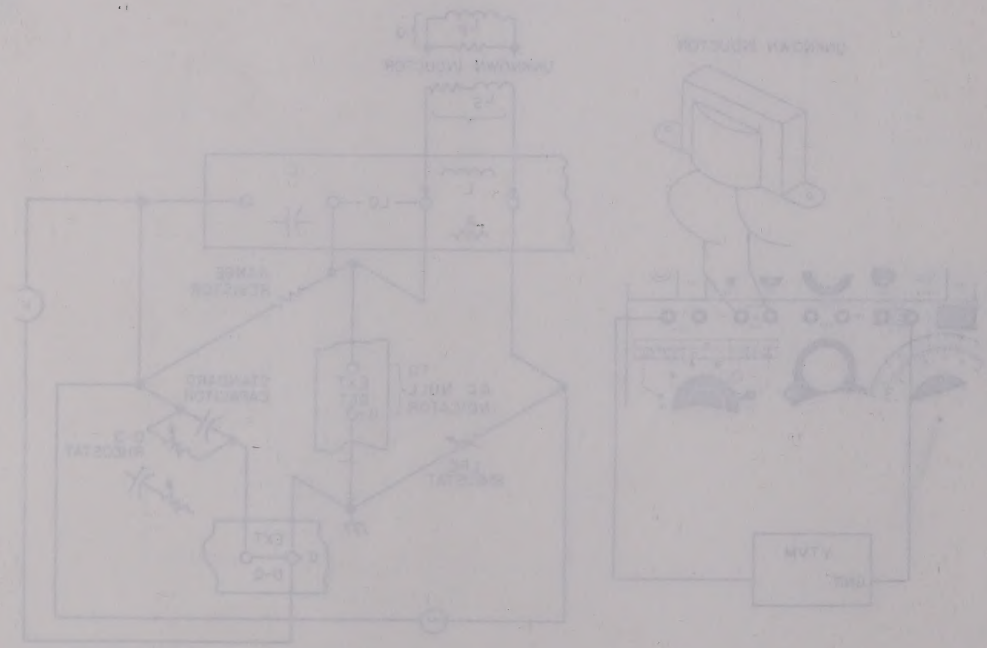


Figure 2-6. Alternating Current Measurement Through Unknown Inductor



through generator terminals (paragraph 2-34) or DC applied through detector terminals (paragraph 2-36).

2-33 *General Precautions.*— Observe the following precautions:

a. The equipment should be set up well away from AC power circuits, since stray AC pickup may change sensitive components being measured or may cause erroneous null indications.

b. The AC impedance of the DC external circuit must be greater than 2000 ohms for maximum sensitivity. An isolating inductor may be used to raise the external impedance; however, it must be well shielded to minimize pickup of stray signals and possible mutual coupling with the inductor being measured. Place the external inductor well away from the inductor being measured. For further reduction of mutual coupling, position the two inductors so that their coil axes are perpendicular. For low-current isolation, a resistor may be used instead of an inductor.

c. The parallel inductance circuit is recommended because it simplifies the problems of current measurement and bridge over-current protection. When the series circuit is used, the DC current divides between the bridge arms and it is difficult to measure. Use of the series circuit also requires making a more careful analysis to avoid excessive current in any of the bridge arms. The equivalent series inductance can easily be calculated using Table IV, if required.

2-34 *Parallel Inductor Measurements With DC Superimposed Through Generator Terminals.*— Supplying the DC signal through the generator terminal allows more current for measuring inductors below 1.2 millihenries. With this connection, the DC is not affected by balancing of the bridge. The circuit is shown in Figure 2-7 and the components have the following functions:

a. For an AC voltage source use an external generator with a frequency output of 1 kc.

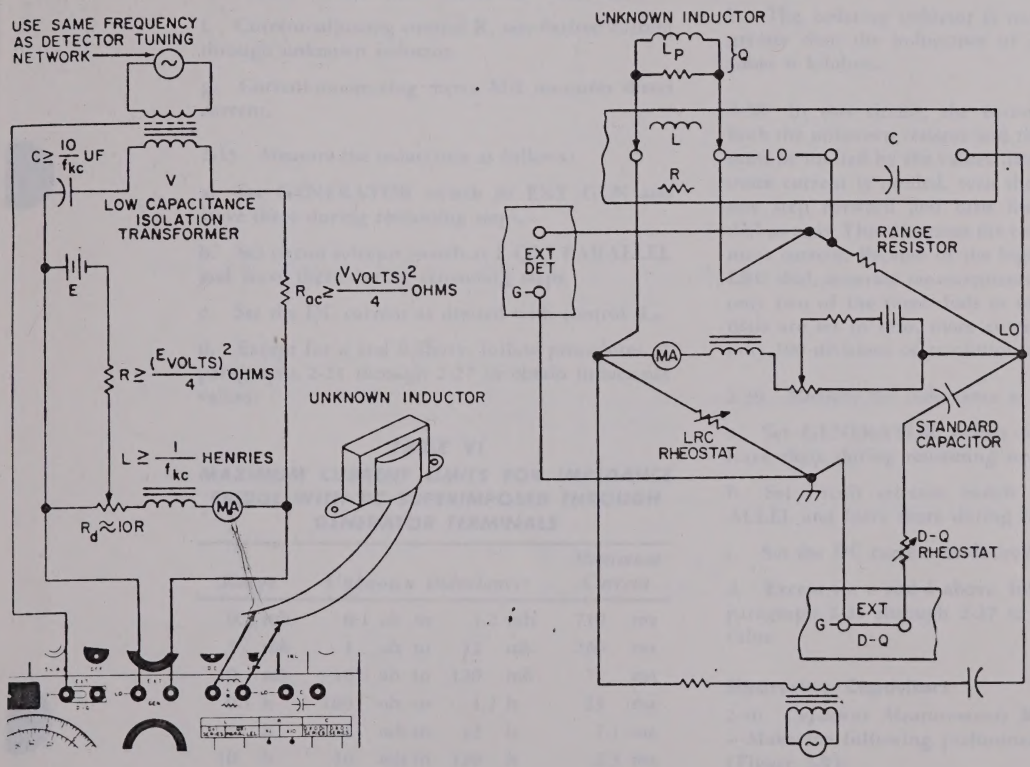
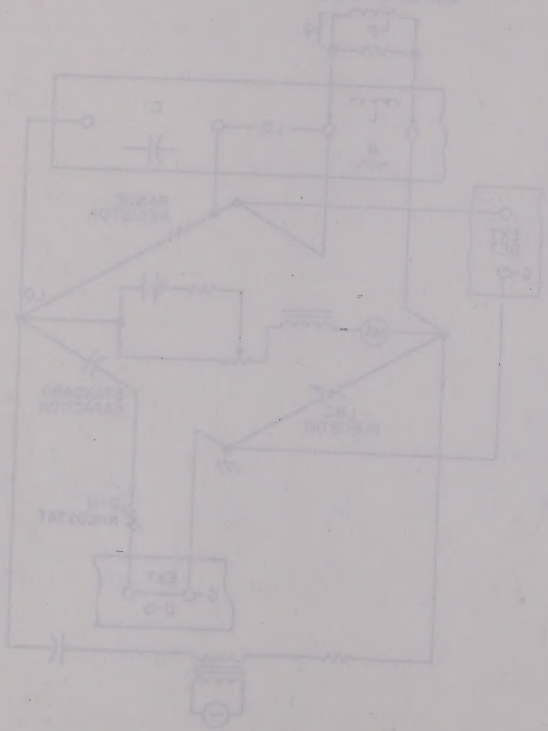


Figure 2-7. Parallel Inductor Measurements With DC Superimposed Through Generator Terminals



b. A battery is recommended for the superimposed DC since most line-operated power supplies have high leakage capacitance to the line and enough DC leakage to be objectionable. A grounded DC supply cannot be used in this case because of leakage capacitance and resistance.

c. Power-limiting resistor R protects the bridge, the detector, and the unknown inductor.

d. Isolating inductor L provides suitable AC circuit impedance. Avoid AC pickup and coupling to the unknown. (This is not necessary if R is greater than 100 ohms.)

e. Isolating capacitor C keeps DC out of generator.

CAUTION

Current rating of the impedance bridge for this test circuit is shown on Table VI. These values must never be exceeded.

f. Current-adjusting control R_d sets desired current through unknown inductor.

g. Current-monitoring meter MA measures direct current.

2-35 Measure the inductance as follows:

a. Set GENERATOR switch to EXT GEN and leave there during remaining steps.

b. Set circuit selector switch at L QX1 PARALLEL and leave there during remaining steps.

c. Set the DC current as desired with control R_d.

d. Except for *a* and *b* above, follow procedures of paragraphs 2-21 through 2-27 to obtain inductance values.

TABLE VI

MAXIMUM CURRENT LIMITS FOR IMPEDANCE BRIDGE WITH DC SUPERIMPOSED THROUGH GENERATOR TERMINALS

Range	*Unknown Inductance*[a]	*Maximum Current*
0.1 mh	0.1 uh to 1.2 mh	710 ma
1 mh	1 uh to 12 mh	230 ma
10 mh	10 uh to 120 mh	71 ma
0.1 h	100 uh to 1.2 h	23 ma
1 h	1 mh to 12 h	7.1 ma
10 h	10 mh to 120 h	2.3 ma
100 h	100 mh to 1200 h	250 ua

[a] Lower limit is one dial division.

2-36 *Parallel Inductor Measurements With DC Superimposed Through Detector Terminals.*— Supplying DC through the detector terminals allows use of higher currents in measuring inductances above 1.2 millhenries (Figure 2-8) However, the DC current will be influenced by the LRC-dial setting. The problems resulting from stray AC pickup are much more serious with this connection because of the direct coupling to the detector. The stray AC pickup might come from the ripple of a DC supply or from capacitive coupling to power lines, or the external generator. There is a possibility of stray field pickup by the isolating inductor (if used), or by inductive coupling to the unknown inductor.

2-37 Except for the following, external circuit components are the same as those listed in paragraph 2-34.

a. For a DC voltage source, a grounded supply can be used because one of the detector terminals is grounded.

b. The isolating inductor is not necessary if R is greater than the inductance of unknown inductor times 6 kilohms.

2-38 In this circuit, the current passes through both the unknown resistor and the LRC rheostat. It must be limited by the values listed in Table VII. If more current is needed, turn the multiplier switch one step forward and turn the outer-most LRC dial to zero. This decreases the resistance and allows more current. Because of the high resolution of the LRC dial, accurate measurements are possible with only two of the three dials in use. If the first two dials are set to zero, more current is possible, but only 100 divisions of resolution are left.

2-39 Measure the inductance as follows:

a. Set GENERATOR switch to EXT GEN and leave there during remaining steps.

b. Set circuit selector switch at L QX1 PARALLEL and leave there during remaining steps.

c. Set the DC current as desired with control R_d.

d. Except for *a* and *b* above, follow procedures of paragraph 2-21 through 2-27 to obtain inductance value.

Measuring Capacitors

2-40 *Capacitor Measurements With AC Applied.* —Make the following preliminary control settings (Figure 2-9):

a. Connect unknown capacitor to C terminals. Be sure to make good contact with the terminals.

CAUTION

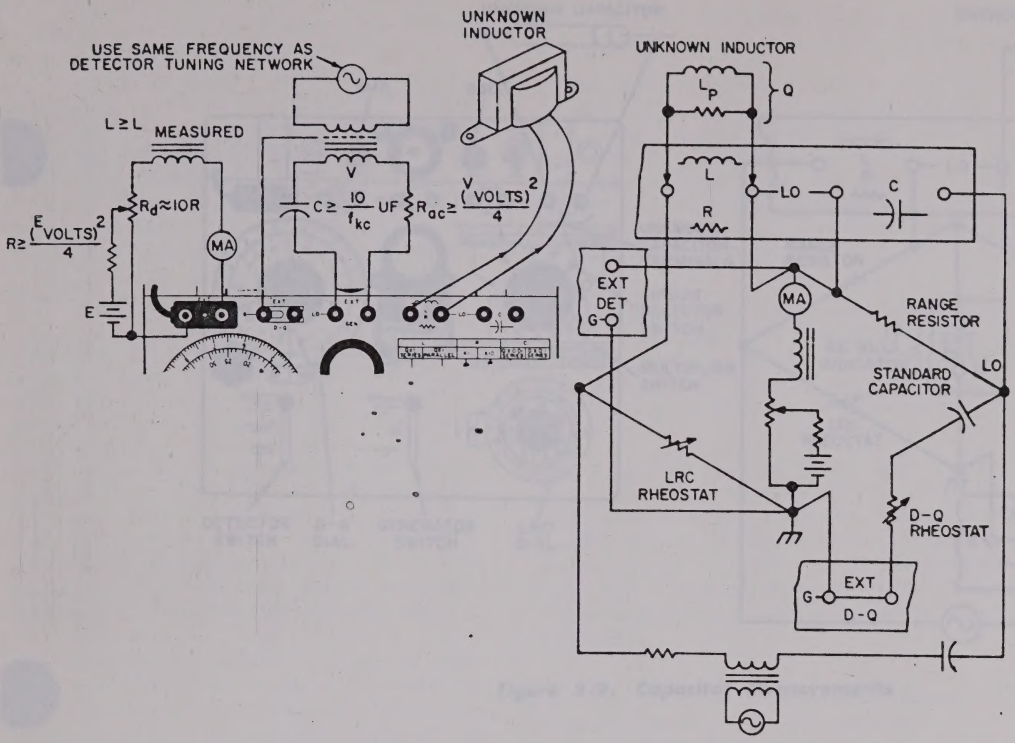


Figure 2-8. Parallel Inductor Measurements With DC Superimposed Through Detector Terminals

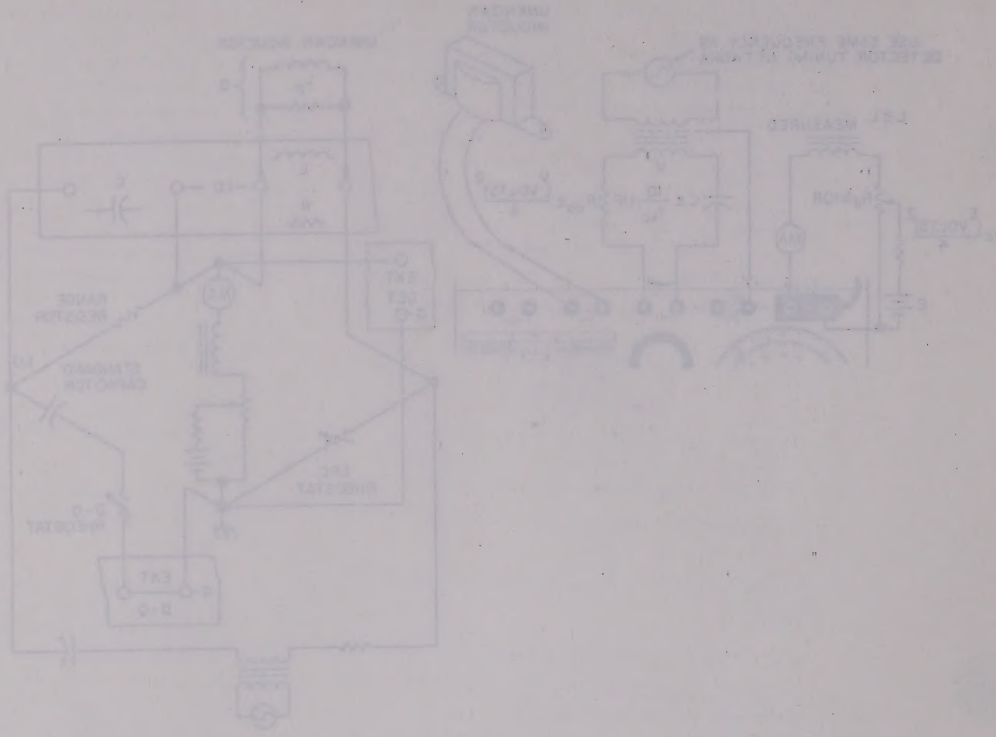
TABLE VII

MAXIMUM CURRENT LIMITS FOR IMPEDANCE BRIDGE WITH DC SUPERIMPOSED THROUGH DETECTOR TERMINALS

Resolution (Dial Divisions)	*LRC Dial*[a]	*Unknown Inductance*[b]	*Maximum Current*
12,005	Outer	100.0 uh to 1200 h	23 ma
1,005	Middle	10.0 uh to 100 h	71 ma
105	Inner	0.1 uh to 10.5 h	270 ma

[a] With care, more current and voltage can be applied. The current rating of the bridge is given above. To use the middle-dial reading, the outer dial must be set to zero. To use the inner-dial reading, the middle and outer dials must be set to zero. These values should never be exceeded.

[b] Lower limit is one division on dial which limits current on lowest range.



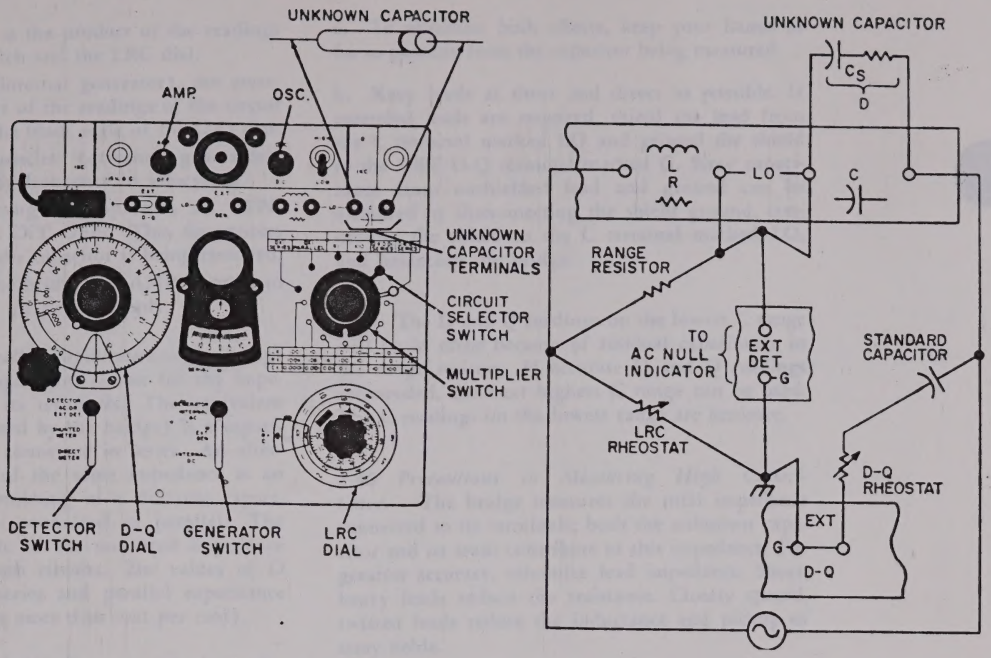


Figure 2-9. Capacitor Measurements

b. Set GENERATOR switch to EXT GEN. This disconnects the generator from the bridge while the controls are being set up.

c. Set AMP. control so that the dot is up. This turns on the impedance bridge and provides medium sensitivity for the detector. The power indicator lamp (red) will go on.

d. Set the OSC. control so that the dot is up. This provides the AC signal.

e. Set the circuit selector switch to the appropriate C position. Use position D X 0.01 for dissipation (D) factors from 0 to 0.105; use position D X 0.1 for dissipation factors from 0.100 to 1.05.

NOTE

Either C position may be used for making capacitance measurements.

f. Set LRC dial at 3.000 and D-Q dial at maximum. These settings facilitate finding the correct range.

g. Set DETECTOR switch to AC OR EXT DET. This connects the detector to the bridge.

h. Set GENERATOR switch at INTERNAL AC. This connects the generator to the bridge.

2-41 Measure the capacitor as follows:

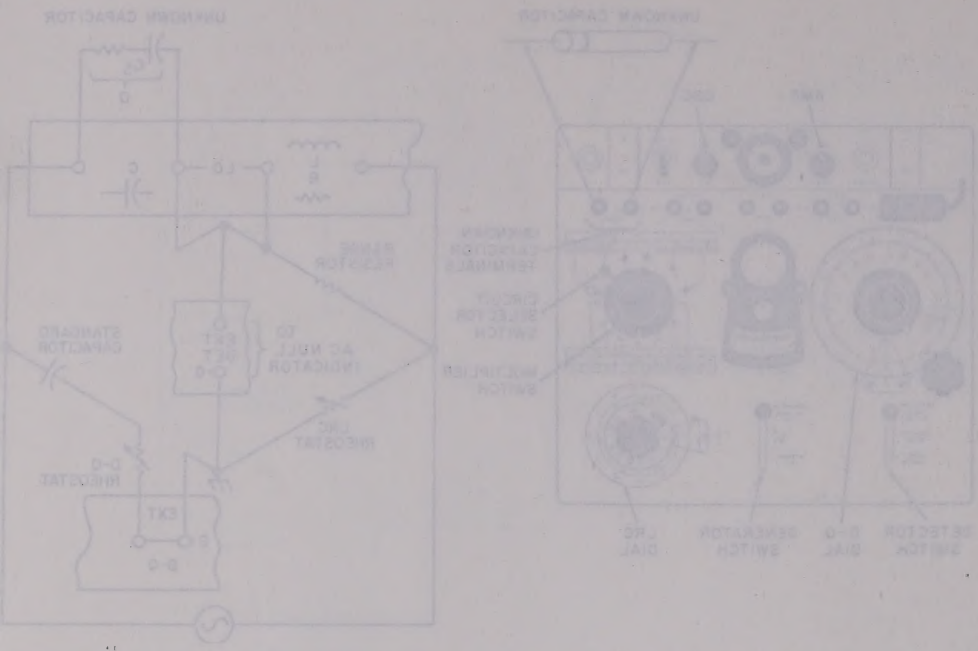
a. Adjust multiplier switch for the widest possible shadow on the AC null indicator. This sets the range so that the value can be found with maximum resolution on the LRC dial.

b. Adjust AMP. and OSC. controls as required. Turn these controls clockwise if the shadow remains nearly closed and does not change for two or more positions of the multiplier switch. Turn the controls clockwise if the shadow remains wide open for two or more positions.

c. Adjust the LRC dial and D-Q dial alternately for the widest and sharpest possible shadow on the AC null indicator. Turn the AMP. and OSC. controls clockwise to increase sensitivity as null is approached.

d. Try the other circuit-selector switch setting if the bridge cannot be balanced.

e. If the LRC-dial reading at balance is less than 1.200, turn the multiplier switch to the next lower setting and readjust the LRC dial for null indication.



f. The measured C is the product of the readings of the multiplier switch and the LRC dial.

g. At 1 kilocycle (internal generator), the measured D is the product of the readings of the circuit selector switch and the black scale of the D-Q dial.

h. At other frequencies (external generator), multiply this value by frequency in kilocycles.

i. Before disconnecting the capacitor, set GENERATOR switch to EXT GEN. This disconnects the generator while the capacitor is being removed.

j. Before leaving the bridge, set AMP. control to OFF. This turns off the power supply.

2-42 *Series and Parallel Capacitance.*—The bridge measures a simple equivalent circuit for the impedance connected to its terminals. The equivalent series circuit (measured by the bridge) is a capacitance and resistance connected in series. An alternate representation of the same impedance is an equivalent circuit consisting of a different capacitance and resistance connected in parallel. The phase and magnitude of the measured impedance are the same for both circuits. For values of D greater than 0.01, series and parallel capacitance differ measurably (by more than 0.01 per cent).

2-43 Although the bridge is measuring the equivalent series circuit, the values of the equivalent parallel circuit can easily be calculated. Series capacitance (C_s) is the value most commonly used in capacitance measurements. To convert from D to Q, or from the series capacitance (C_s) to the equivalent parallel capacitance (C_p), use the following steps:

a. For the series circuit:

$$Q = \frac{1}{D}$$

D and Q in per unit, R_{series} in kilohms,

$$R_{series} = \frac{D}{2\pi fC_{series}}$$

f in kilocycles, $2\pi = 6.28$, C_{series} in microfarads.

b. For the equivalent parallel circuit:

$$C_{parallel} = \frac{C_{series}}{(1 + D^2)}$$

$$R_{parallel} = \frac{1}{D} \times \frac{1}{2\pi fC_{parallel}}$$

Except $2\pi fC_{parallel}$

2-44 *Precautions in Measuring Low Capacitance.*—In measuring low capacitance, hum pickup and stray capacitance must be kept to a minimum.

a. To minimize both effects, keep your hands as far as possible from the capacitor being measured.

b. Keep leads as short and direct as possible. If extended leads are required, shield the lead from the C terminal marked LO and ground the shield to the EXT D-Q terminal marked G. Stray capacitance from unshielded lead and ground can be measured by disconnecting the shield ground, connecting the shield to the C terminal marked LO, and balancing the bridge.

2-45 The D and Q readings on the lowest C range will be in error because of residual capacitance in the range resistor. If accurate D and Q readings are needed, the next highest C range can be used. The C readings on the lowest range are accurate.

2-46 *Precautions in Measuring High Capacitance.*— The bridge measures the total impedance connected to its terminals; both the unknown capacitor and its leads contribute to this impedance. For greatest accuracy, minimize lead impedance. Short, heavy leads reduce the resistance. Closely spaced, twisted leads reduce the inductance and pickup of stray fields.

2-47 *Use of External Generator and/or Detector.*— Procedures for use are the same as those for resistance measurement (Paragraph 2-19).

2-48 *Measuring AC Voltage Across Unknown Capacitor.*— Perform the following:

a. Before measuring the capacitor, connect a vacuum-tube voltmeter as shown in Figure 2-10.

b. Measure the capacitor (balance the bridge).

c. Read the voltmeter. When the bridge is balanced, the voltage is equal to the AC voltage across the unknown capacitor, but the capacitor has not been loaded by the voltmeter. The bridge readings, however, may be incorrect while the voltmeter is connected.

d. Disconnect the voltmeter and measure the capacitor again to find true C and D.

2-49 *Capacitor Measurements With Superimposed DC.*— Some capacitors need a polarizing voltage. For example, electrolytic and tantalytic capacitors may be damaged by the reverse half-cycle of AC or RF generator voltage. Even if they are not damaged, erroneous readings may result.

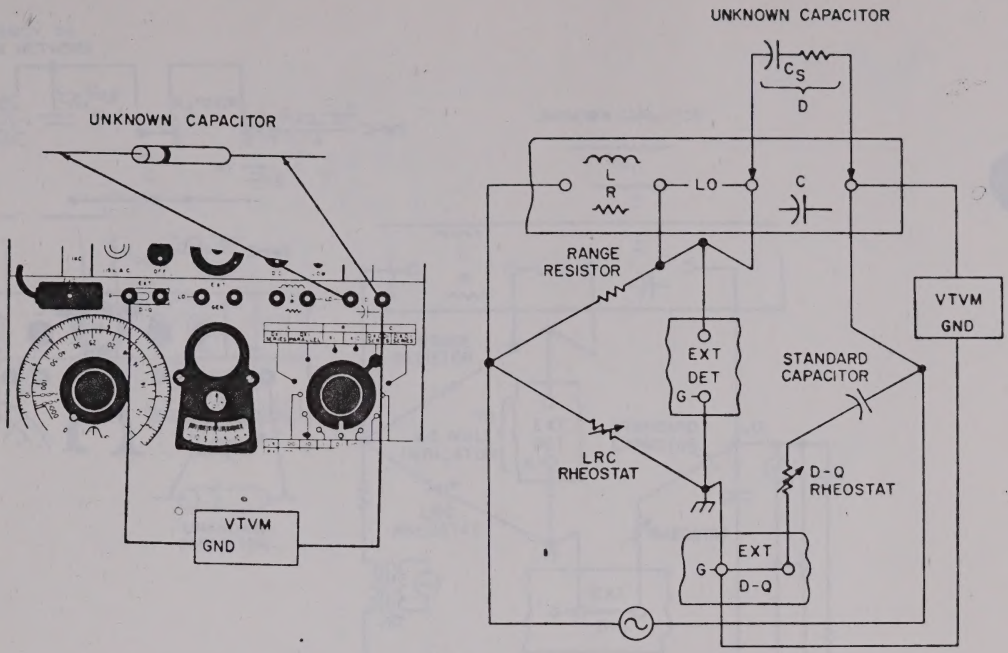


Figure 2-10. AC Voltage Measurement Across Unknown Capacitor

2-50 A polarizing voltage may not always be needed. If the generator voltage is kept very low (typically below ½ volt), the capacitor will not be damaged, and readings will be reasonably accurate, considering the wide tolerances typical of electrolytic and tantalytic capacitors. Because of high detector sensitivity, accurate balance can be obtained with very low oscillator voltages. When operating with low oscillator voltage, make sure the detector sensitivity is kept high.

2-51 *General Precautions.*— Observe the following general precautions if using a polarizing voltage:

a. The DC should be supplied through the generator terminals. When this is done, both bridge current paths include a series capacitor. All of the DC voltage will appear across both the unknown capacitor and the standard capacitor in the bridge circuit.

b. Avoid stray AC pickup in the external DC circuit; it may affect sensitive components being measured or given erroneous null indicator readings.

c. The AC impedance of the external DC circuit must be less than 200 ohms for maximum sensitivity.

d. A grounded DC generator cannot be used because one of the detector terminals is grounded. Leakage capacitance and resistance from the DC source to ground will occur across the bridge arms and may cause significant errors.

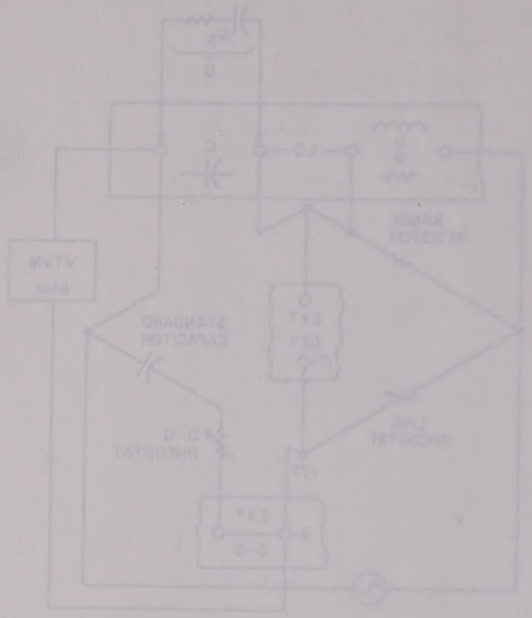
e. Most line-operated DC power supplies have high leakage capacitance to the AC line and enough DC leakage to be objectionable. An insulated, isolated battery is recommended.

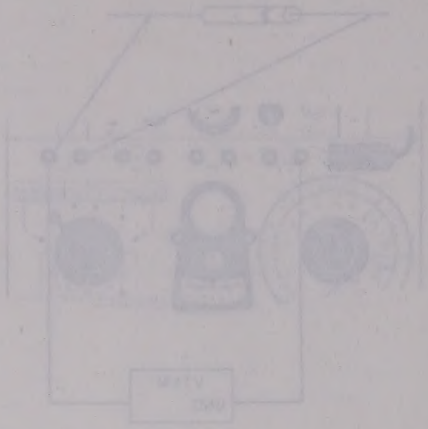
2-52 *Parallel Capacitance Measurement With DC Superimposed Through Generator Terminals.* — Components of this circuit (Figure 2-11) have the following functions:

a. The isolation transformer keeps DC from external AC generator.

b. Power-limiting resistor R limits power applied to the bridge to 1 watt in order to protect all of the bridge circuit in case the unknown capacitor is shorted accidentally.

c. DC voltage source E should not exceed 300 volts for protection of the standard capacitor in the bridge.





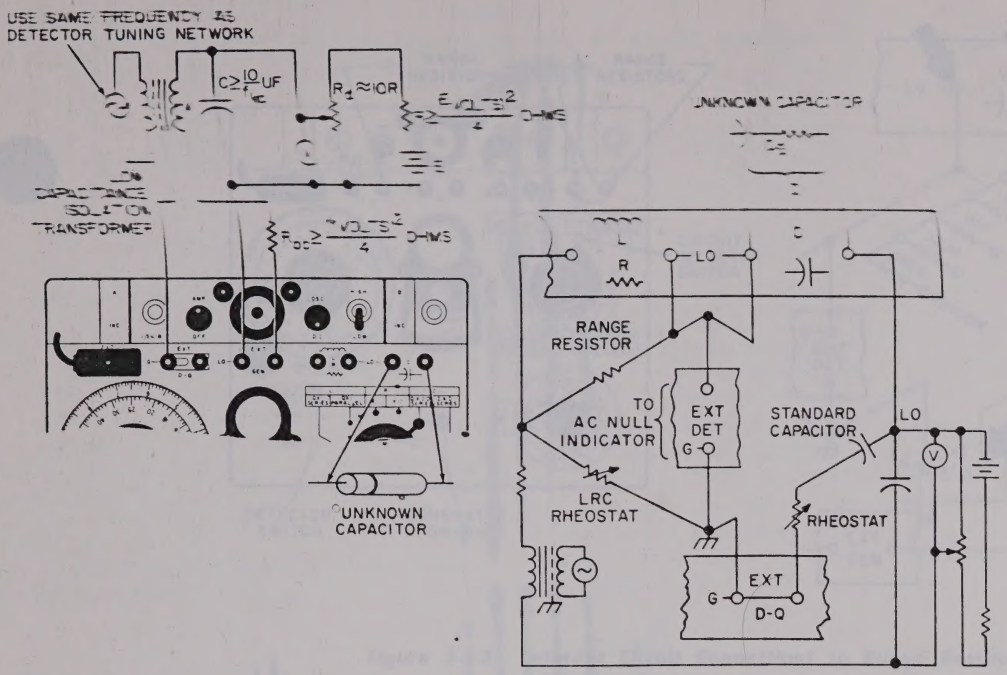


Figure 2-11. Parallel Capacitance Measurement With DC Superimposed Through Generator Terminals

d. Voltage-adjusting control R sets the polarizing voltage across the unknown capacitor.

e. Voltmeter V indicates voltage across the unknown capacitor.

2-53 Set the DC voltage as required and measure capacitance as described in paragraphs 2-40 through 2-46 (except leave GENERATOR switch at position AC OR EXT GEN). For low-leakage capacitors, the voltage across the unknown capacitor is equal to the voltmeter reading. For capacitors with relatively high-leakage resistance, the voltage drop across the range resistor becomes significant and the voltage across the capacitor may be calculated as follows:

a. Measure the DC resistance of the capacitor with the impedance bridge or with a vacuum-tube voltmeter.

b. Calculate the voltage (E_C) across the unknown capacitor according to the following equation:

$$E_C = E_{in} \frac{R_C}{R_C + R_R}$$

where E_C = DC voltage across unknown capacitor,

E_{in} = DC voltage indicated by voltmeter,

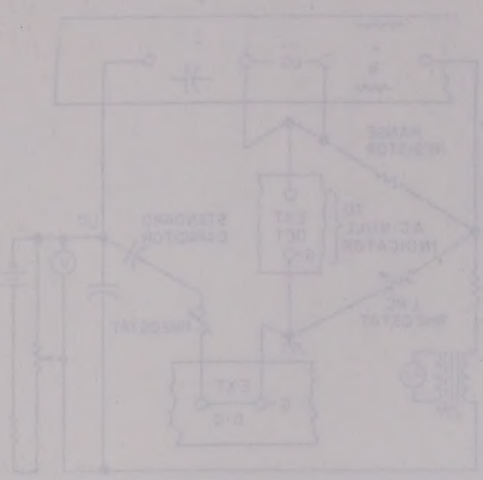
R_C = DC resistance of the unknown capacitor, and

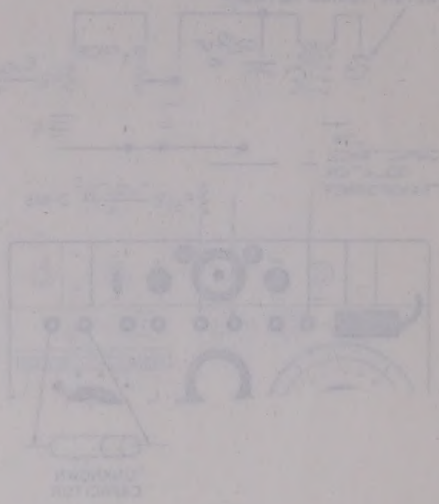
R_R = resistance of range resistor (Table VIII).

Using the Bridge Elements in External Circuit

2-54 *External Connections to Range Resistors.*— Nine standard resistors may be used as follows (Figure 2-12):

a. Set circuit selector switch and multiplier switch as desired (Table VIII).





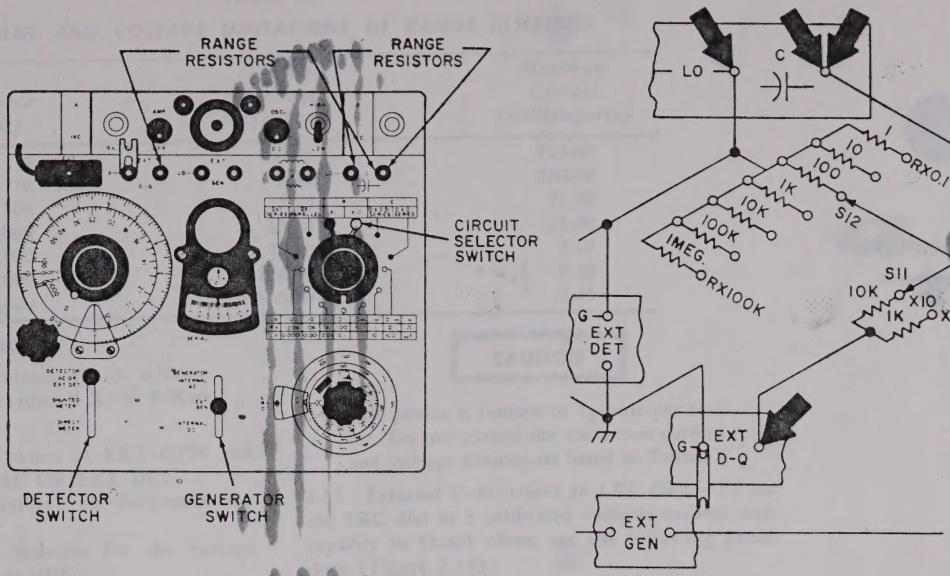


Figure 2-12. External Circuit Connections to Range Resistor

TABLE VIII

EXTERNAL CONNECTIONS FOR STANDARD RANGE RESISTORS

External Circuit Connections Points	External Circuit Connection Points								
	Between C Terminals							Between High C and EXT D-Q	
Multiplier Switch Setting	R X-100k	R X-10k	R X-1k	R X-100	R X-10	R X-1	R X-0.1		
Resistance	1 meg[a]	100 k[b]	10 k[b]	1 k[b]	100[b]	10[b]	1[c]	10 k[b]	1 k[b]
Circuit Selector Switch Setting								R X1	R X10

[a] Accuracy = ± 0.15%
[b] Accuracy = ± 0.05%
[c] Accuracy = ± 0.25%

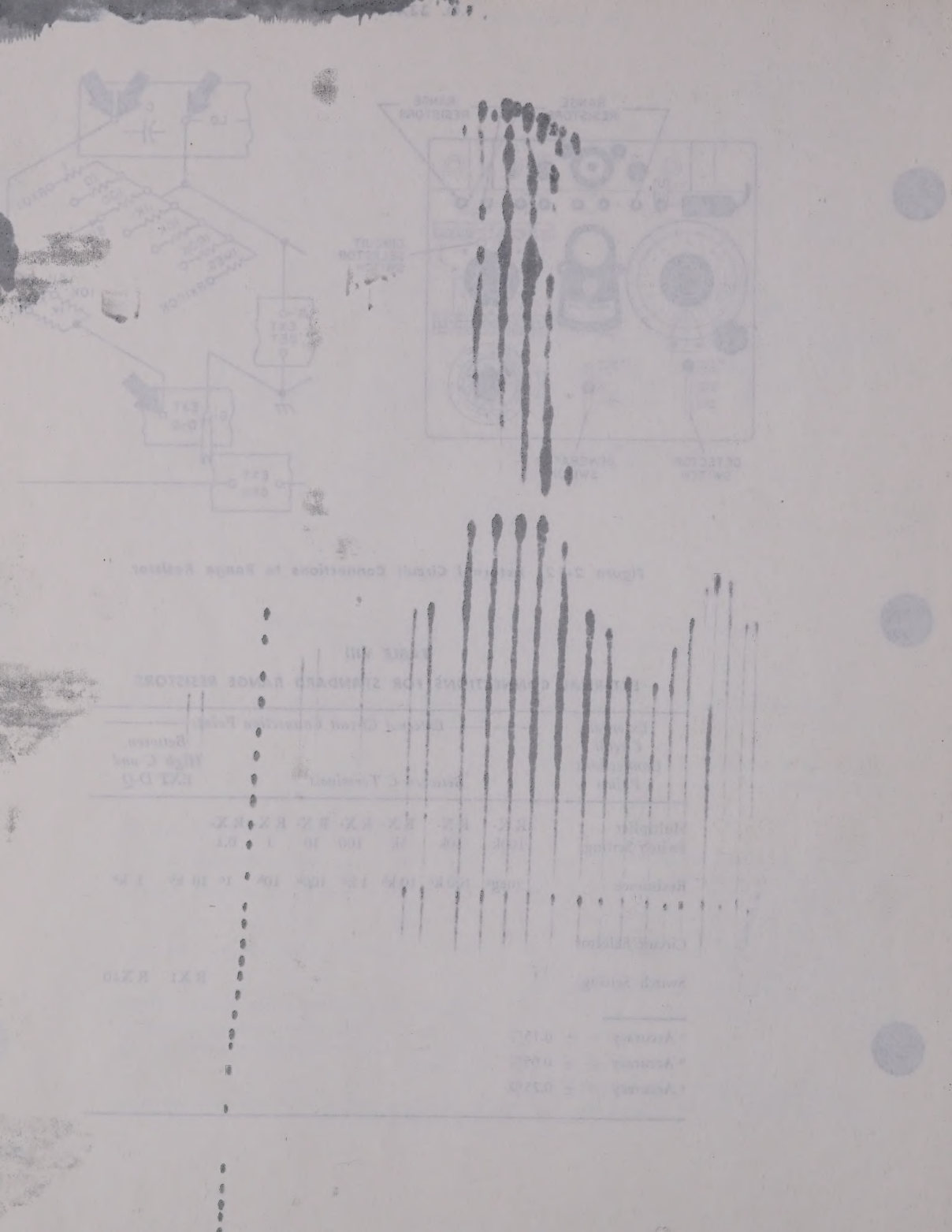


TABLE IX

CURRENT AND VOLTAGE LIMITATIONS OF RANGE RESISTORS

Resistance (ohms)	*Maximum Voltage (volts)*	*Maximum Current (milliamperes)*
1	0.71	710.00
10	2.30	230.00
100	7.10	71.00
1,000	23.00	23.00
10,000	71.00	7.10
100,000	230.00	2.30
1,000,000	250.00	0.25

NOTE

When using C terminals, circuit selector switch may be set at either R X1 or R X10 position.

b. Set GENERATOR switch at EXT GEN and DETECTOR switch at AC OR EXT DET.

c. Open EXT D-Q jumper to disconnect the chassis ground.

d. Available standard resistors for the various ranges are shown in Table VIII.

CAUTION

Safe power is limited to ½ watt per resistor. Do not exceed the maximum current and voltage limitations listed in Table IX.

2-55 *External Connections to LRC Dial.*—To use the LRC dial as a calibrated variable resistor with capacity to 12,005 ohms, use the following procedure (Figure 2-13):

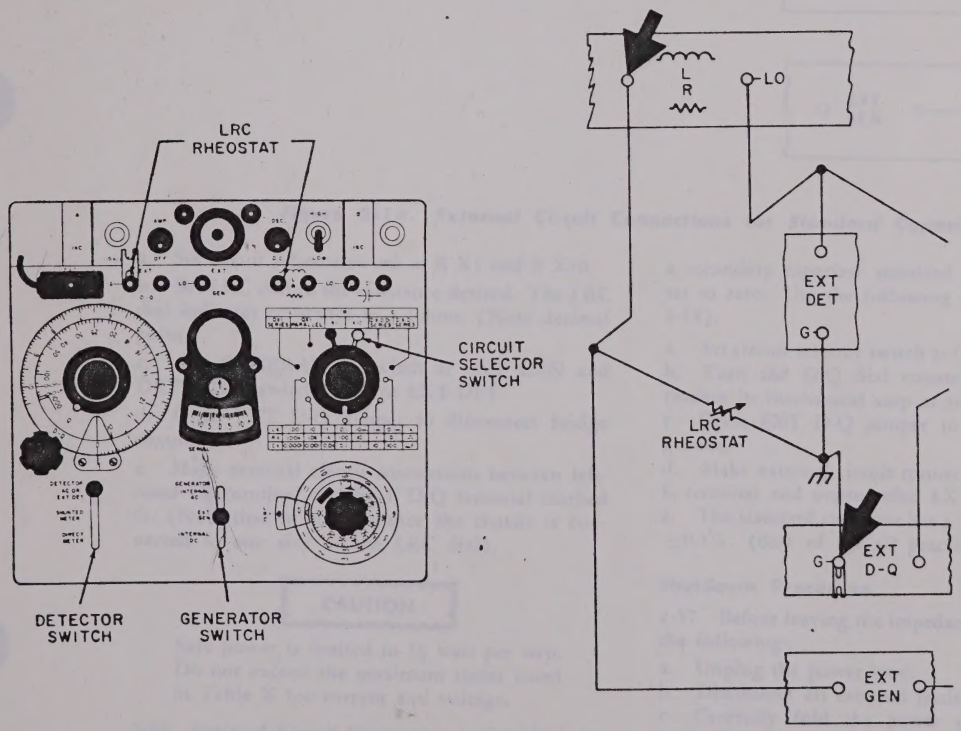
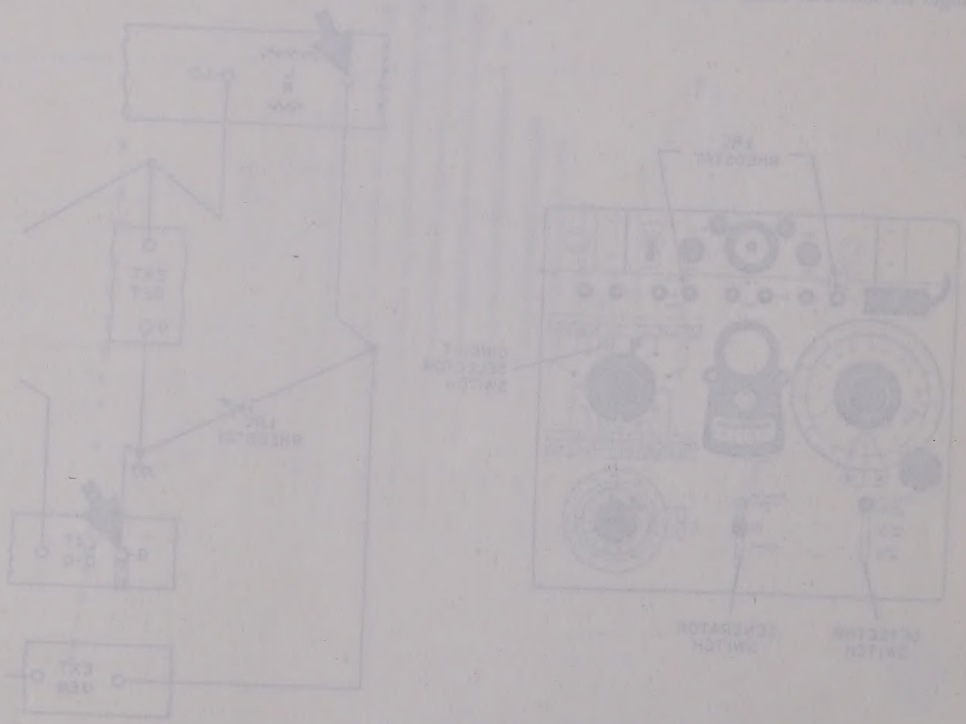


Figure 2-13. External Circuit Connections to LRC Dial



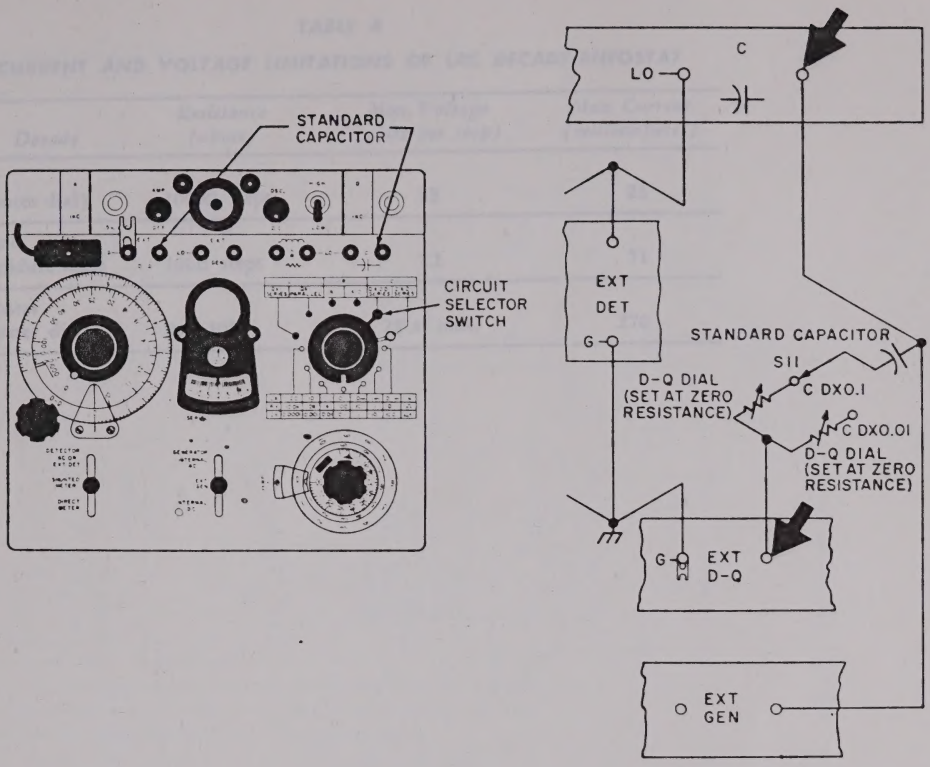


Figure 2-14. External Circuit Connections for Standard Capacitor

a. Set circuit selector switch at R X1 and R X10.

b. Set LRC dial to the resistance desired. The LRC dial indicates resistance in kilohms. (Note decimal point.)

c. Set GENERATOR switch at EXT GEN and DETECTOR switch at AC or EXT DET.

d. Open EXT D-Q jumper to disconnect bridge circuit.

e. Make external circuit connections between left-hand LR terminal and EXT D-Q terminal marked G. (Note that in this instance the chassis is connected to one side of the LRC dial).

CAUTION

Safe power is limited to ½ watt per step. Do not exceed the maximum limits listed in Table X for current and voltage.

2-56 *External Circuit Connection to Standard Capacitor.* — The 0.1-uf capacitor may be used as a secondary capacitor standard with the D-Q dial set to zero. Use the following procedure: (Figure 2-14).

a. Set circuit selector switch at C D X 0.01 SERIES.

b. Turn the D-Q dial counterclockwise until it reaches its mechanical stop at zero.

c. Open EXT D-Q jumper to disconnect chassis ground.

d. Make external circuit connections between high C terminal and ungrounded EXT D-Q terminal.

e. The standard capacitor has a value of 99,880 uuf ±0.1%. (0.01 uf for all practical purposes).

Shutdown Procedure

2-57 Before leaving the impedance bridge, perform the following:

a. Unplug the power cord.

b. Disconnect all external leads.

c. Carefully fold the power cord and the test leads. Store them in their respective compartments.

d. Replace the lid.

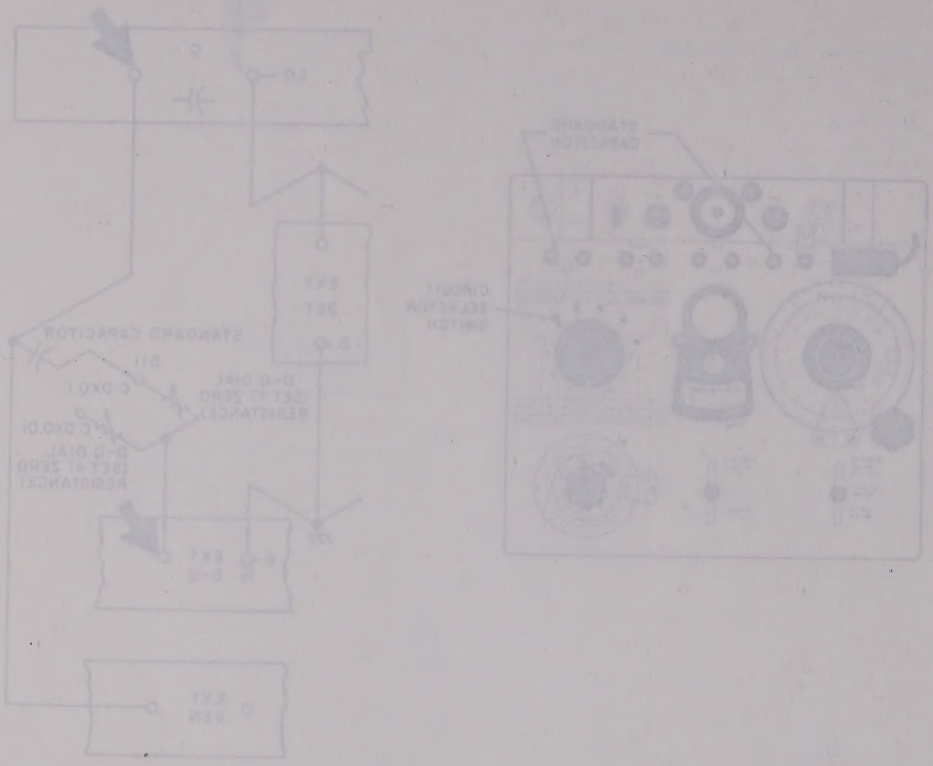
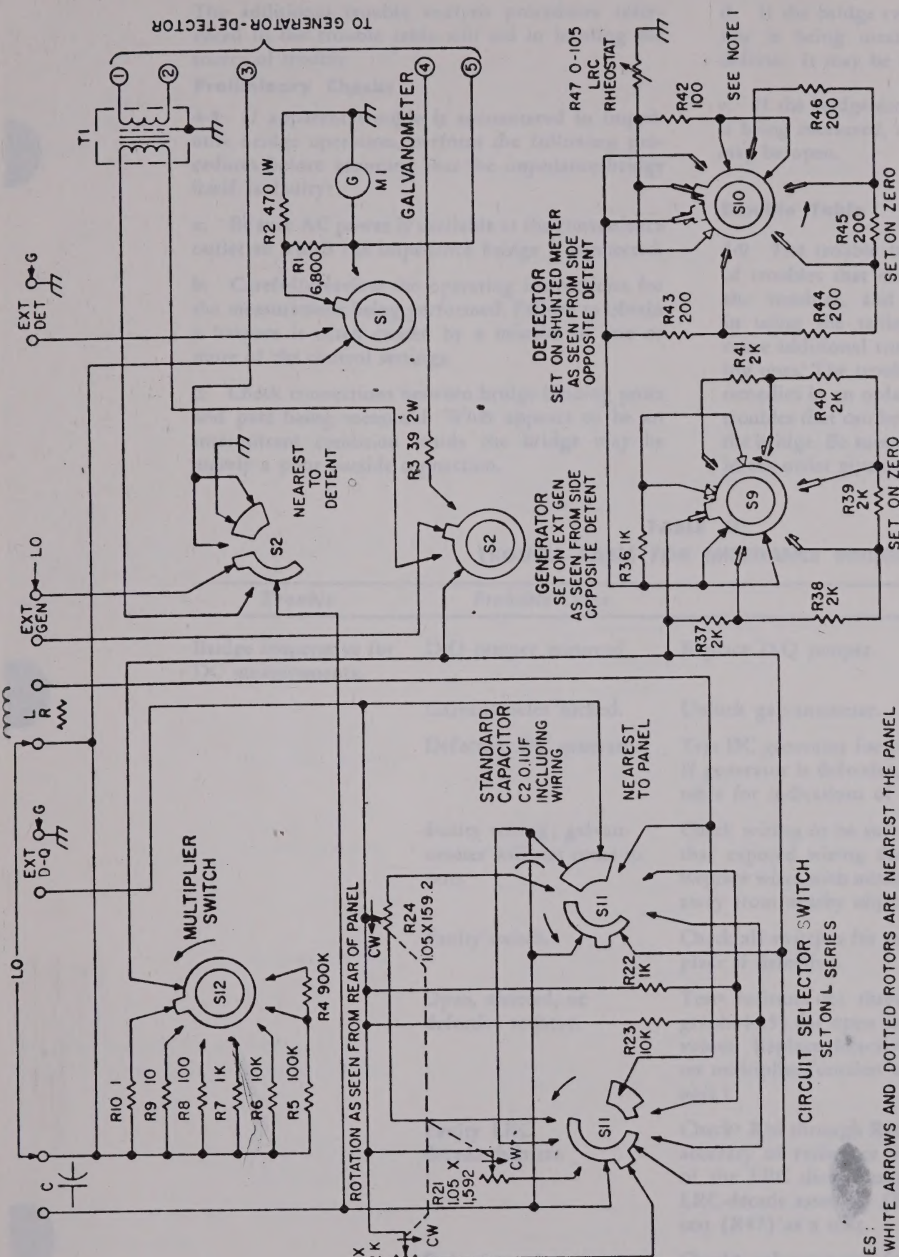


TABLE X

CURRENT AND VOLTAGE LIMITATIONS OF LRC DECADE-RHEOSTAT

Decade	*Resistance (ohms)*	*Max. Voltage (volts per step)*	*Max. Current (milliamperes)*
First (outer dial)	1000Ω steps	23	23
Second (middle dial)	100Ω steps	7.1	71
Rheostat (inner dial)	0 — 105	28 at max.	270



NOTES:
1. WHITE ARROWS AND DOTTED ROTORS ARE NEAREST THE PANEL
2. RESISTANCES ARE IN OHMS. K=1000 OHMS.
3. S9, S10, S11, S12, AS SEEN FROM REAR OF PANEL.

Figure 4-1. Bridge Circuit, Wiring Diagram

The additional trouble analysis procedures referenced in the trouble table will aid in locating the source of trouble.

Preliminary Checks

4-8 If apparent trouble is encountered in impedance bridge operation, perform the following procedures before assuming that the impedance bridge itself is faulty:

a. Be sure AC power is available at the convenience outlet to which the impedance bridge is connected.

b. Carefully review the operating instructions for the measurement being performed. Failure to obtain a balance is often caused by a mistake in one or more of the control settings.

c. Check connections between bridge binding posts and part being measured. What appears to be an intermittent condition inside the bridge may be merely a poor outside connection.

d. If the bridge cannot be balanced when a capacitor is being measured, check the capacitor for defects. It may be open or shorted.

e. If the bridge cannot be balanced when a resistor is being measured, check the resistor for defects. It may be open.

Trouble Table

4-9 The trouble table (Table XI) lists symptoms of troubles that may occur, the probable causes of the troubles, and corrective action. Be careful in using the table; unnecessary disassembly may cause additional troubles instead of correcting existing ones. The trouble table lists possible causes and remedies in an orderly sequence, describing first the troubles that can be corrected without disassembling the bridge. Be sure to investigate the probable causes in the order given.

TABLE XI

TROUBLE TABLE FOR IMPEDANCE BRIDGE

Trouble	*Probable Cause*	*Remedy*
Bridge inoperative for DC measurements.	D-Q jumper removed.	Replace D-Q jumper.
	Galvanometer locked.	Unlock galvanometer.
	Defective DC generator.	Test DC generator for proper voltage (paragraph 4-12). If generator is defective, refer to other symptoms in this table for indications of probable trouble.
	Faulty wiring; galvanometer will not come to zero.	Check wiring to be sure that no short circuits exist and that exposed wiring does not touch the metal cabinet. Replace wires with missing insulation. Move bare wiring away from nearby objects.
	Faulty switch.	Check all switches for proper contacts and operation: replace if defective.
	Open, shorted, or defective resistor.	Test[a] resistors R1 through R10 and R22, R23 (paragraph 4-25) for open and shorted circuits and for rated values. Replace defective resistor. (R4 through R10 are on multiplier-function assembly, which is replaced as a unit.)
	Faulty LRC decade-rheostat.	Check[a] R36 through R46 and R47 for continuity and for accuracy of resistance values corresponding to settings of the LRC dial (paragraph 4-27). Replace defective LRC-decade assembly (R36 through R46) or LRC rheostat (R47) as a unit.
	Defective galvanometer.	Check[a] galvanometer for proper operation (paragraph 4-15); replace if defective.

[a] Depot only.

(Continued)

TABLE XI. TROUBLE TABLE FOR IMPEDANCE BRIDGE (Continued)

Trouble	*Probable Cause*	*Remedy*
Bridge inoperative for AC resistance measurements.	D-Q jumper removed.	Replace D-Q jumper.
	Detector unplugged.	Plug detector into EXT DET terminals.
	Defective AC generator.	Test AC generator for proper voltage (paragraph 4-17). If generator is defective, refer to other symptoms in this table for indications of probable trouble.
	Faulty switch.	Check[a] all switches for proper contact and operation; replace if defective.
	Open, shorted, or defective resistor.	Test[a] resistors R4 through R10 (paragraph 4-23), R22, and R23 (paragraph 4-25) for open and shorted circuits and for rated values. Replace defective resistor. (R4 through R10 are on multiplier-function assembly, which is replaced as a unit.)
Bridge inoperative for inductance and capitance measurements.	D-Q jumper removed.	Replace D-Q jumper.
	Detector unplugged.	Plug detector into EXT DET terminals.
	Defective AC generator.	Test AC generator for proper voltage (paragraph 4-17).
	Faulty switch.	Check[a] all switches for proper contacts and operation; replace if defective.
	Open, shorted, or defective resistor.	Check[a] resistors R4 through R10 (paragraph 4-23), and R21, R24 (paragraph 4-29) for open and shorted circuits, and for rated values.
	Faulty LRC decade-rheostat.	Check[a] R36 through R46 and R47 (paragraph 4-27) for continuity and for accuracy of resistance values corresponding to settings of the LRC dial. Replace defective LRC-decade assembly (R36 through R46) or LRC rheostat (R47) as a unit.
	Faulty capacitor C2.	Check[a] capacitor C2 for an open or shorted circuit, for leakage, and for proper value (paragraph 4-34); replace if defective.
Readings inaccurate on resistance measurement.	Faulty LRC decade-rheostat.	Check[a] R36 through R46 and R47 (paragraph 4-27) for accuracy of resistance values corresponding to settings of the LRC dial. Replace defective LRC Dekastat assembly (R36 through R46) or LRC rheostat (R47) as a unit.
	LRC dials improperly positioned on shaft.	Position[a] dials properly (paragraph 4-46).
Readings inaccurate on inductance or capacitance measurement.	Faulty capacitor C2.	Check[a] capacitor C2 for leakage and for proper value (paragraph 4-34); replace if defective.

[a] Depot only.

(Continued)

TABLE XI. TROUBLE TABLE FOR IMPEDANCE BRIDGE (Continued)

Trouble	Probable Cause	Remedy
Bridge inoperative for AC resistance measurements.	D-Q jumper removed.	Replace D-Q jumper.
	Detector inoperative.	Plug detector into EXT DET terminals.
	Defective AC generator.	Test AC generator for proper voltage (paragraph 4-17). If generator is defective, refer to other symptoms in this table for indications of probable trouble.
	Faulty switch.	Check all switches for proper contact and operation; replace if defective.
	Open, shorted, or defective resistor.	Test resistors R4 through R10 (paragraph 4-23), R21, and R23 (paragraph 4-23) for open and shorted circuits and for rated values. Replace defective resistor. (If through R10 are on multiplier-function assembly, which is replaced as a unit.)
Bridge inoperative for inductance and capacitance measurements.	D-Q jumper removed.	Replace D-Q jumper.
	Detector inoperative.	Plug detector into EXT DET terminals.
	Defective AC generator.	Test AC generator for proper voltage (paragraph 4-17).
	Faulty switch.	Check all switches for proper contact and operation; replace if defective.
	Open, shorted, or defective resistor.	Check resistors R1 through R10 (paragraph 4-23), and R21, R23 (paragraph 4-23) for open and shorted circuits, and for rated values.
	Faulty LRC decade-resistor.	Check R36 through R46 and R47 (paragraph 4-27) for continuity and for accuracy of resistance values corresponding to settings of the LRC dial. Replace defective LRC decade assembly (R36 through R46) or LRC thermistor (R47) as a unit.
	Faulty capacitor C2.	Check capacitor C2 for an open or shorted circuit, for leakage, and for proper value (paragraph 4-34); replace if defective.
Reading inaccurate on resistance measurement.	Faulty LRC decade-resistor.	Check R36 through R46 and R47 (paragraph 4-27) for accuracy of resistance values corresponding to settings of the LRC dial. Replace defective LRC decade assembly (R36 through R46) or LRC thermistor (R47) as a unit.
	LRC dials improperly positioned on shaft.	Position dials properly (paragraph 3-46).
Reading inaccurate on inductance or capacitance measurement.	Faulty capacitor C2.	Check capacitor C2 for leakage and for proper value (paragraph 4-34); replace if defective.

(Continued)

TABLE XI. TROUBLE TABLE FOR IMPEDANCE BRIDGE (Continued)

Trouble	*Probable Cause*	*Remedy*
Readings inaccurate on inductance or capacitance measurement. *(continued)*	Defective D-Q rheostat. The following sections are operative for the indicated circuit selector switch settings: L SERIES R25 L PARALLEL R24 C D X 0.01 R24 C D X 0.1 R21	Check[a] D-Q rheostats (paragraph 4-29). Replace entire assembly if any one rheostat is defective.
	D-Q dial improperly positioned on shaft.	Position[a] dial properly (paragraph 4-52).
Power indicator lamp fails to go on.	No AC line voltage.	Trace failure in AC power source and correct.
	AMP. control knob is not positioned correctly.	Reset control knob so that white dot is at OFF when control shaft is at extreme left position.
	Defective fuse.	Check for continuity. If necessary, replace with ½-amp fuse.
	Power indicator lamp burned out.	Replace with No. 47 bulb (paragraph 4-39).
	AC power switch on AMP. control defective.	Check and replace if necessary.
	Defective power cable.	Repair or replace cable.
	Defective power transformer.	Check for continuity of filament winding; replace transformer if necessary.
Line fuse blows instantly when power switch is turned on.	Defective filter capacitors.	Check capacitors C114 and C115 for possible short to ground; replace if necessary.
	Defective rectifier.	Check all rectifiers for possible short to ground; replace if necessary.
	Defective power transformer.	Check windings for possible short circuit; replace if necessary.
Some tube filaments fail to light.	Defective tubes.	Check continuity of filaments; replace defective units.
	Broken filament lead.	Check circuit continuity; repair if necessary.
Failure of 10-volt DC supply.	Defective selenium rectifier (CR103).	Check forward and back resistance of rectifiers; back resistance should be at least 10 times forward resistance. Replace if necessary.
	Defective 10-volt transformer winding.	Check continuity of 10-volt winding; replace transformer if necessary.

[a] Depot only.

(Continued)

TABLE XI. TROUBLE TABLE FOR IMPEDANCE BRIDGE (Continued)

Trouble	*Probable Cause*	*Remedy*
ailure of 270-volt)C supply.	Defective filter capacitors.	Check capacitors C114 and C115 for possible short circuit to ground; replace if necessary.
	Defective selenium rectifiers (CR101 and CR102).	Check forward and back resistance of rectifiers; back resistance should be at least 10 times forward resistance. Replace if necessary.
	Open transformer winding.	Check continuity of high-voltage transformer winding; replace transformer if necessary.
lo DC generator)utput.	Wrong switch setting.	Use correct switch positions.
	Defective switches.	Check switch continuities; replace switch if necessary.
)scillator failure.	Defective tube.	Replace V103.
	No plate voltage.	Check power supply. Check resistor R149; replace if defective.
	Defective plug-in oscillator network.	Check values of all components in plug-in unit; replace defective components. Check for possible shorts in plug-in unit.
ailure to see green arget on visual null ndicator.	No plate or target voltage.	Check power supply; see "Failure of 270-volt DC supply in this table.
	Defective tube.	Replace V102.
ailure to see null ignal on visual null ndicator.	Null amplifier defective.	Plug headphones in pin jacks above AC null indicator and listen for amplifier signal; if none, see below.
	Defective AC generator.	Check generator output (paragraph 4-16); locate and correct trouble.
	Defective tube.	Replace V102.
	Defective input cable.	Check continuity of all leads including shield; repair as necessary.
	Defective bridge circuit.	Check[a] all circuits associated with instrument; correct as necessary.
Detector input signal is not amplified.	Defective amplifier tube.	Replace V101.
	No plate voltage.	Check associated circuits for open resistors (R140, R141, R142) or short-circuited capacitor (C106, C108, or C124); replace defective components.
		Remove amplifier plug-in network; if amplifier resumes operation, check plug-in unit for possible short to ground.
		Check power supply; see "Failure of 270-volt DC power supply in this table.

[a] Depot only.

(Continued)

TABLE XI. TROUBLE TABLE FOR IMPEDANCE BRIDGE (Continued)

Trouble	*Probable Cause*	*Remedy*
	Open cathode circuit.	Check all cathode circuit components (R137, R138, C104 and C105); replace defective components.
	Defective input wiring or control potentiometer.	Check input circuitry and continuity of R136. Replace defective components.
Failure to amplify oscillator signal.	Defective tube.	Replace V103.
	Open cathode circuit.	Check R148; replace if defective.
	Defective input circuit.	Check R151, C113 and control potentiometer R150; replace defective components.
	No plate voltage.	Check power supply; see "Failure at 270-volt DC supply" in this table.
		Check continuity of primary winding of T1; replace T1 if necessary.
No generator output.	Defective coupling transformer.	Check continuity of secondary of T1 and associated wiring; replace transformer if necessary.
Output signal off-frequency.	Oscillator network out of adjustment.	Readjust C123 to give correct frequency (paragraph 4-54).

TABLE XII
TUBE-SOCKET VOLTAGE AND RESISTANCE DATA

Tube	*Pin*	*Voltage (volts)*	*Resistance (ohms)*	*Tube*	*Pin*	*Voltage (volts)*	*Resistance (ohms)*
V101	1	90	580 Kilohms	V102	4	220	100 Kilohms
	2	...	50 Kilohms[a]		5	0	0
	3	1.1	4700		6	0	0
	4	0	0	V103	1	140	100 Kilohms
	5	0	0		2	...	2.5 Megohms
	6	135	210 Kilohms		3	0	0
	7	...	1.2 Megohms		4	0	0
	8	1.1	1500		5	0	0
	9	6.3 AC	....		6	210	100 Kilohms
V102	1	6.3 AC	....		7	...	50 Kilohms[a]
	2	20	1.3 Megohms		8	1.1	820
	3	...	2.7 Megohms	9	9	6.3 AC	....

[a] Depends on setting of AMP. and OSC. controls.
Measurement considerations:
1. AMP. control clockwise so white dot is up.
2. OSC. control clockwise so white dot is up.

Tube Socket Voltage and Resistance Data

4-10 Voltages and resistances measured to ground from the pins of tubes V101, V102, and V103 are tabulated in Table XII. These are typical values measured with the oscillator operating and with no input to the detector. Any reading differing from that indicated by more than 15 per cent is a probable indication of trouble. Use volt-ohm-milliameter KS-14510 for these measurements.

Transformer Winding Resistance

4-11 Winding resistances of transformers T1 and T2 are given in Table XIII. Primary resistance of T1 is measured with the two primary windings connected in parallel for 115-volt operation. Resistance of either winding alone is twice the indicated value.

TABLE XIII
TRANSFORMER WINDING RESISTANCE

Transformer	*Winding Terminals*	*Resistance (ohms)*
T1	Primary (on terminal strip)	25
	Secondary	150
T2	Primary (on terminal strip)	38
	6.3-volt secondary (red-red)	0.5
	Low-voltage secondary (wht-wht)	3.5
	High-voltage secondary (blk-blk)	500

DC Generator Output-Voltage Check

4-12 Set the controls as follows:

a. DETECTOR switch to AC OR EXT DET.
b. GENERATOR switch to INTERNAL DC.
c. Circuit selector switch to C D X 0.01 SERIES.
d. High C terminal to negative lead of voltmeter.
e. High LR terminal to positive lead of voltmeter.

4-13 Set volt-ohm-milliammeter KS-14510 to 600 volts DC full scale and flip DC generator HIGH-LOW toggle switch to HIGH. Voltmeter should read 300 volts approximately. Any serious deviation from this value indicates probable trouble in the half wave rectifier circuit in the power supply.

4-14 Flip DC generator HIGH-LOW toggle switch to LOW and set voltmeter range to 60 volts full scale. Voltmeter should read 10 volts approximately. Any serious deviation from this value indicates probable trouble in the full-wave rectifier circuit in the power supply.

Galvanometer Performance Check

4-15 The galvanometer performance check is described in the following steps. Set controls as follows:

a. Circuit selector switch to R XI.
b. Multiplier switch to RX 100k.
c. GENERATOR switch to EXT GEN.
d. DETECTOR switch to SHUNTED METER.
e. LRC to 0.000.
f. AMP. control dot up.
g. OSC. control to DC (extreme CCW).
h. DC generator HIGH-LOW toggle switch to LOW.
i. Galvanometer to unlocked, zero position.
j. GENERATOR switch to INTERNAL DC.

4-16 With these control settings, the galvanometer pointer should be deflected approximately one division to the left of zero. Next, move the DETECTOR switch to DIRECT METER. The pointer should deflect 10 to 15 divisions to the left of zero. If these requirements are not met, test R1 and R2 resistance values (at depot only).

AC Generator Frequency and Performance Check

4-17 Make initial connection and settings as follows:

a. DETECTOR switch to AC OR EXT DET.
b. GENERATOR switch to INTERNAL AC.
c. Circuit selector switch to L QXI SERIES.
d. D-Q dial completely counterclockwise.
e. Remove plug from EXT DET terminals.
f. Remove shorting bar from EXT D-Q terminals.
g. OSC. control completely clockwise.

4-18 Connect oscilloscope to EXT D-Q terminals with oscilloscope ground connected to G terminal. Set controls as follows:

Tube Socket Voltage and Resistance Data

4-10. Voltage and resistance measured to ground from the pins of tube V101, V102, and V103 are tabulated in Table XII. These are typical values measured with the multimeter operating and with no input to the generator. Any reading differing from that indicated by more than 15 per cent is a probable indication of trouble. Use voltage-to-ohm factor K5-11310 for these measurements.

Transformer Winding Resistance

4-11. Winding resistances of transformers T1 and T2 are given in Table XIII. Primary resistance of T1 is measured with the two primary windings connected in parallel for 115-volt operation. Resistance of either winding alone is twice the indicated value.

TABLE XII

TRANSISTORIZED WINDING RESISTANCE

Transformer	Winding Terminals	Resistance (ohms)
T1	Primary (or terminal strip)	.25
	Secondary	.150
T2	Primary (or terminal strip)	.38
	5-volt secondary (red-red)	.0.5
	Low-voltage secondary (yellow-yellow)	.8.5
	High-voltage secondary (blue-blue)	700

DC Generator Output-Voltage Check

4-12. Set the controls as follows:

a. INJECTOR switch to AC OR EXT DET.

b. GENERATOR switch to INTERNAL DC.

c. Current selector switch to 1 D X 0.01 SERIES.

d. High E terminal to negative lead of voltmeter.

e. High EE terminal to positive lead of voltmeter.

4-13. Set voltmeter multiplier, K5-11310 to 300 volts DC. Unit scale and the DC generator HIGH-LOW toggle switch to HIGH. Voltmeter should read 300 volts approximately. Any serious deviation from this value indicates probable trouble in the full-wave rectifier circuit in the power supply.

Galvanometer Performance Check

4-14. The galvanometer performance check is described in the following steps. Set controls as follows:

a. Circuit selector switch to R X1.

b. Multiplier switch to RX 100K.

c. GENERATOR switch to EXT GEN.

d. DETECTOR switch to SHUNTED METER.

e. ERC to 0.000.

f. AMP control fully up.

g. OSC control to DC (extreme CCW).

h. DC generator HIGH-LOW toggle switch to LOW.

i. Galvanometer to unlocked, zero position.

j. GENERATOR switch to INTERNAL DC.

4-15. With these control settings, the galvanometer pointer should be deflected approximately one division to the left of zero. Next, move the DETECTOR switch to DIRECT METER. The pointer should deflect 10 to 15 divisions to the left of zero. If these requirements are not met, use R1 and R2 to adjust values (at depot only).

AC Generator Frequency and Performance Check

4-16. Make initial connections and settings as follows:

a. DETECTOR switch to AC OR EXT DET.

b. GENERATOR switch to INTERNAL AC.

c. Circuit selector switch to 1 CXI SERIES.

d. D-Q dial completely counterclockwise.

e. Remove plug from EXT DET terminals.

f. Remove shorting bar from EXT D-Q terminals.

g. OSC control completely clockwise.

4-17. Connect oscilloscope to EXT D-Q terminals with oscilloscope ground connected to Q terminal. Set controls as follows:

a. Set oscilloscope sweep for 0.5 millisecond per horizontal division.

b. Set oscilloscope sensitivity for 10 volts per vertical division.

c. Obtain trace on oscilloscope screen and center the trace on horizontal axis. Center trace horizontally so that trace starts at one of the horizontal divisions.

d. Ten half-cycles of the displayed waveform should fill ten horizontal divisions ±4 per cent. (This corresponds to a 1000-cycle frequency.) Peak-to-peak amplitude should be approximately 40 volts.

AC Detector Performance Check

4-19 Set controls as follows:

a. DETECTOR switch to AC OR EXT DET.
b. GENERATOR switch to INTERNAL AC.
c. Circuit selector switch to L QXI SERIES.
d. Multiplier switch to LX 100h.
e. LRC dial to 0.000.
f. OSC control completely clockwise.
g. D-Q completely counterclockwise.

4-20 When these control settings are made, the shadow of the AC null indicator should be completely open. Next, set the LRC dial to 3.000; the shadow should close.

Bridge-Circuit Precision Resistor and Rheostat Checks (DEPOT ONLY)

4-21 Accuracy of the following checks is limited by the accuracy of the test equipment used. When made with the ohmmeter indicated in the following procedures, the check is a rough one that will indicate open circuits. It is not likely that these checks will show up shorted turns.

4-22 If a precision Wheatstone bridge is available, the test procedures described in paragraphs 4-23 to 4-33 may be used as accuracy checks of the precision resistors and rheostats.

4-23 *Range Resistor Check.*—Make initial control settings and connections as follows for checking range resistors R4 through R10:

a. DETECTOR switch to AC OR EXT DET.
b. GENERATOR switch to EXT GEN.
c. Circuit selector switch to C DX0.01 SERIES.
d. AMP. control to OFF.
e. Connect ohmmeter test leads to LR terminals.

4-24 Ohmmeter should read as indicated for the following multiplier-switch positions:

RX 100k (R4 + R5)	1 megohm
RX 10k (R5)	100,000 ohms
RX 1k (R6)	10,000 ohms
RX 100 (R7)	1,000 ohms
RX 10 (R8)	100 ohms
RX 1 (R9)	10 ohms
RX 0.1 (R10)	1 ohm

4-25 *Standard Resistor Check.* — Set controls as follows for checking standard resistors R22 and R-23:

a. DETECTOR switch to AC OR EXT DET.
b. GENERATOR switch to EXT GEN.
c. Circuit selector switch to R XI.

4-26 Connect ohmmeter test leads from high C terminal to EXT D-Q terminal marked G. The D-Q jumper must be in position. Ohmmeter reading should be as indicated for the following circuit selector-switch positions:

R X1 (R23)	10,000 ohms
R X10 (R22)	1000 ohms

4-27 *LRC Decade-Rheostat Check.* — Set controls as follows for checking the LRC decades and rheostat:

a. DETECTOR switch to AC OR EXT DET.
b. GENERATOR switch to EXT GEN.
c. Circuit selector switch R X1.

4-28 Connect ohmmeter test leads to high LR terminal and EXT D-Q terminal marked G. The D-Q jumper must be in position. Ohmmeter readings at D-Q dial positions should be as follows:

a. To check rheostat R47, set two outer dials at zero. Ohmmeter reading, in ohms, should equal inner-dial setting from 0 to 105.

b. To check decade resistors R42 through R46, set all dials at zero. Then rotate middle dial from positions 1 through 9. Ohmmeter reading should increase, 100 ohms at a time, from 0 to 900 ohms.

c. To check decade resistors R36 through R41, set all dials at zero. Then rotate outer dial to positions 1 through 11. Ohmmeter reading should increase, 1000 ohms at a time, from 0 to 11,000 ohms.

4-29 *D-Q Rheostats Check.* — D-Q rheostats R21, R-24, and R-25 are checked separately as described in paragraphs 4-30 through 4-33. A precision decade

resistor and precision capacitor are required for checking R21 and R24.

4-30 *D-Q Rheostat R25.* — With the controls set up as follows, connect ohmmeter leads to high C terminal and EXT D-Q terminal marked G. Leave the D-Q jumper in position. Ohmmeter should indicate about 16,000 ohms.

a. DETECTOR switch to AC OR EXT DET.

b. GENERATOR switch to EXT GEN.

c. Circuit selector switch to L QXI SERIES.

d. Multiplier switch to LX 100h.

e. D-Q dial (outer) to 10.

4-31 *D-Q Rheostats R21 and R24.*—To check R21 and R24, connect a decade resistor in series with 0.1-uf precision capacitor to the C terminals and set controls as follows:

a. DETECTOR switch to AC OR EXT DET.

b. GENERATOR switch to EXT GEN.

c. AMP. control dot up.

d. OSC. control dot up.

e. LRC dials 1.000.

f. Multiplier switch CX 0.1.

4-32 To check R24, set circuit selector switch to C DX 0.01 SERIES. The D-Q dial should be adjusted for a galvonometer null as external resistance is inserted. The D-Q dial readings for the indicated external resistance should be as follows:

External Decade Resistance	*D-Q Dial Setting*
18 ohms	1.0
82 ohms	5.0
161 ohms	10.0

4-33 To check R21, set circuit selector switch to C D X 0.1 SERIES. The D-Q dial should be adjusted for galvanometer null as external resistance is inserted. The D-Q dial readings for the indicated external resistance should be as follows:

External Decade Resistance	*D-Q Dial Setting*
161 ohms	1.0
798 ohms	5.0
1594 ohms	10.0

Standard Capacitor Check (DEPOT ONLY)

4-34 To check the standard capacitor in the bridge, use the capacitance of the 0.1-uf standard capacitor General Radio Model 1409T. Measure the capacitance of this capacitor in the standard manner. If the capacitor measures other than 0.1 uf $\pm$ 0.1%, remove the bridge from the cabinet, and disconnect the internal 0.1-uf standard capacitor. Then compare the readings of the two capacitors using the B521 component bridge. (The Model 1409T standard capacitor should be assumed to be accurate.) The two standard capacitors should be of the same value within $\pm$0.1%.

NOTE

The value measured by the B521 component is not necessarily a true value, since the standard capacitors are more accurate than the measuring device. However, the readings should be within the specified limit of each other.

REPLACEMENT PROCEDURES

4-35 Replacement procedures for most parts of the impedance bridge are obvious. Supplementary instructions for those operations which require them are described in paragraphs 4-36 through 4-53. Parts location is shown in the illustrations in Section 7. Refer to the bridge circuit wiring diagram, Figure 4-1, for circuit connections of the bridge. Schematic diagrams of the bridge and amplifier-oscillator assembly are contained in Section 5.

Removal and Replacement of the Chassis

4-36 Remove the chassis as follows:

a. With the panel facing up, remove four panel mounting screws.

b. Holding panel in place, turn cabinet on its side with panel facing front.

c. Carefully slide chassis from cabinet.

4-37 To replace the chassis, stand the cabinet so that the opening faces up and lower the chassis into place. Replace the mounting screws.

Replacement of Fuse

4-38 Replace the fuse as follows:

a. Remove fuseholder (25, Figure 7-3). Withdraw fuseholder, with fuse attached, from the power-cord compartment.

b. Remove old fuse and attach new fuse.

c. Replace fuse and fuseholder.

Replacement of Power Indicator Lamp

4-39 Replace the power indicator lamp as follows:

a. Remove chassis from cabinet (paragraph 4-36).

b. Remove duct strip (1, Figure 7-3) for access to lamp.

c. Replace lamp (2, Figure 7-3).

d. Replace duct strip and put chassis back into cabinet.

Replacement of Vacuum Tubes

4-40 AC null indicator V102 can be replaced from the front. Remove shield (13, Figure 7-3) and pull the tube straight out.

4-41 For access to tubes V101 and V103, remove chassis from cabinet (paragraph 4-36).

Replacement of Generator and Detector Networks

4-42 The networks are secured to the sides of the amplifier-oscillator assembly with snap fasteners. Push the network away from the amplifier-oscillator assembly to disengage the snap fastener. The network can then be withdrawn.

4-43 When replacing a network, first engage the plug in the network base with the socket in the amplifier-oscillator assembly. Then engage the snap fastener.

Replacement of LRC Decade-Rheostat (DEPOT ONLY)

4-44 The LRC decade-rheostat is a two-part assembly consisting of a rheostat driven by the center LRC dial and two resistance decades, driven by the outer dials. The entire assembly must be replaced as a unit.

4-45 Remove the LRC decade-rheostat as follows:

a. Remove LRC dial index (16, Figure 7-2).

b. Remove the three LRC dials (17, 18, 19, Figure 7-2). Each dial is secured to its shaft with two socket-head set-screws.

c. Remove rheostat mounted behind chassis (30, Figure 7-2).

d. Remove hardware attaching multiplier function assembly (31, Figure 7-2) to chassis (30, Figure 7-2).

e. Remove hexagon nut from shaft bushing on front of main panel.

f. Remove and tag leads from components not attached to assembly.

g. Remove two screws holding chassis (30, Figure 7-2) and move chassis to rear for clearance needed to remove the decades.

4-46 Replace the LRC decade-rheostat as follows:

a. See the LRC decades on Figure 4-1; set both shafts of decade to their 0 positions. This should be done first because it is very difficult to check switch position after the decade is installed.

b. Mount the decade to the main panel with the hexagon nut and lockwasher supplied.

c. Replace chassis (30, Figure 7-2) and all hardware previously removed.

d. Install LRC rheostat.

e. Install dials but do not tighten setscrews.

f. Install index (16, Figure 7-2).

g. Align 0 on dials (18, 19, Figure 7-2) with scribed mark on index, and tighten dial setscrews.

h. Turn the LRC rheostat to its detent position and align 00 on dial (17, Figure 7-2) with scribed mark on index without moving rheostat shaft. Tighten dial setscrews.

i. Replace leads previously disconnected (refer to paragraph 4-45*f*).

Replacement of Multiplier-Function Assembly (DEPOT ONLY)

4-47 The multiplier-function assembly (Figure 7-4) consists of the circuit selector switch and the multiplier switch. It must be replaced as a unit.

4-48 Remove the multiplier-function assembly as follows:

a. Remove knob (20, Figure 7-2) and pointer (21, Figure 7-2).

b. Remove hexagon nut securing multiplier-function assembly to main panel.

c. Perform *d*, *e*, *f*, and *g* of papagraph 4-45.

d. Remove multiplier-function assembly.

4-49 Replace the multiplier-function assembly as ollows:

Turn both switch shafts clockwise (viewed from ont) into their detents.

Install multiplier-function assembly through ole in main panel. Replace, but do not tighten, taching hexagon nut.

Replace chassis (30, Figure 7-2) and all attach- g hardware.

Turn rear hexagon nut on multiplier-function ssembly shaft so that it bears lightly against rear of ain panel.

Tighten hexagon nut on front of main panel.

Replace knob (20, Figure 7-2) and pointer (21, igure 7-2). Line up each with its most-clockwise anel marking and tighten setscrews.

eplacement of D-Q Rheostat (DEPOT ONLY)

4-50 The three-section D-Q rheostat must be re- laced as a unit; single sections cannot be replaced.

4-51 Remove the D-Q rheostat as follows (40, igure 7-2):

. Remove D-Q dial index (12, Figure 7-2).

. Loosen socket-head setscrews on dial (13, Fig- re 7-2).

. Remove, from rear of main dial, hexagon nut olding knob (11, Figure 7-2) and vernier assembly 14, Figure 7-2).

. Remove dial, knob, and vernier assembly.

. Remove clamps (28, 29, Figure 7-2) and take ut two screws and one nut securing D-Q rheostat to hassis.

. Remove and tag leads from components not ttached to assembly.

. Take out three screws holding D-Q rheostat to ain panel and remove D-Q rheostat.

4-52 Replacement of the D-Q rheostat is the re- verse of disassembly. Before tightening dial, align it as follows:

a. Repeat the test procedure of paragraph 4-30 and 4-31.

b. Set external decade resistance to 18 ohms and circuit selector switch to C D X 0.1 SERIES.

c. Balance the bridge.

d. Without removing the D-Q rheostat shaft, set the dial to 1.00.

e. Check D-Q dial alignment at all three resistance values given in paragraph 4-32.

Replacement of Galvanometer (DEPOT ONLY)

4-53 To replace the galvanometer, remove the two screws just above the zero-set knob and pull the galvanometer straight out. No leads are attached. Install new galvanometer and replace screws.

Frequency Adjustment of AC Generator

4-54 The trimmer capacitor located in the generator network adjusts the generator frequency after need for adjustment has been determined by results of the AC generator frequency and performance checks (paragraphs 4-17 and 4-18).

4-55 Perform the following preliminary adjustments as follows:

a. Turn the impedance bridge so that the panel is vertical.

b. Remove the generator network (1, Figure 7-2), take out the single cover screw, and remove the cover.

c. Replace the uncovered network into the chassis.

d. Perform the AC generator frequency and performance checks (paragraphs 4-17 and 4-18).

4-56 Adjust the AC generator as follows:

a. Adjust trimmer capacitor as required to make 10 half-cycles of the displayed waveform fill exactly 10 horizontal divisions on the oscilloscope screen.

b. Replace the network cover.

c. Recheck the adjustment with the cover in place.

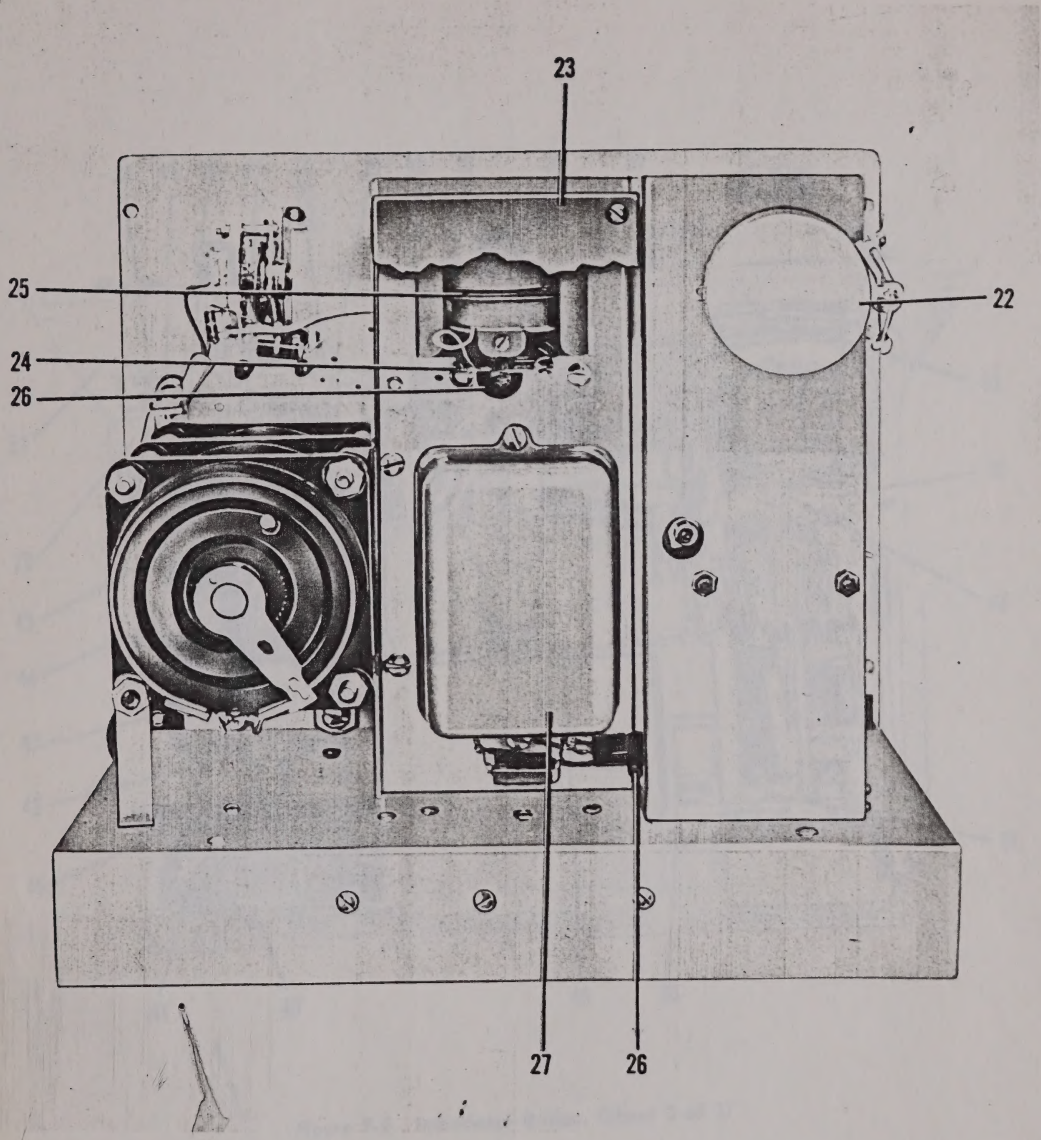
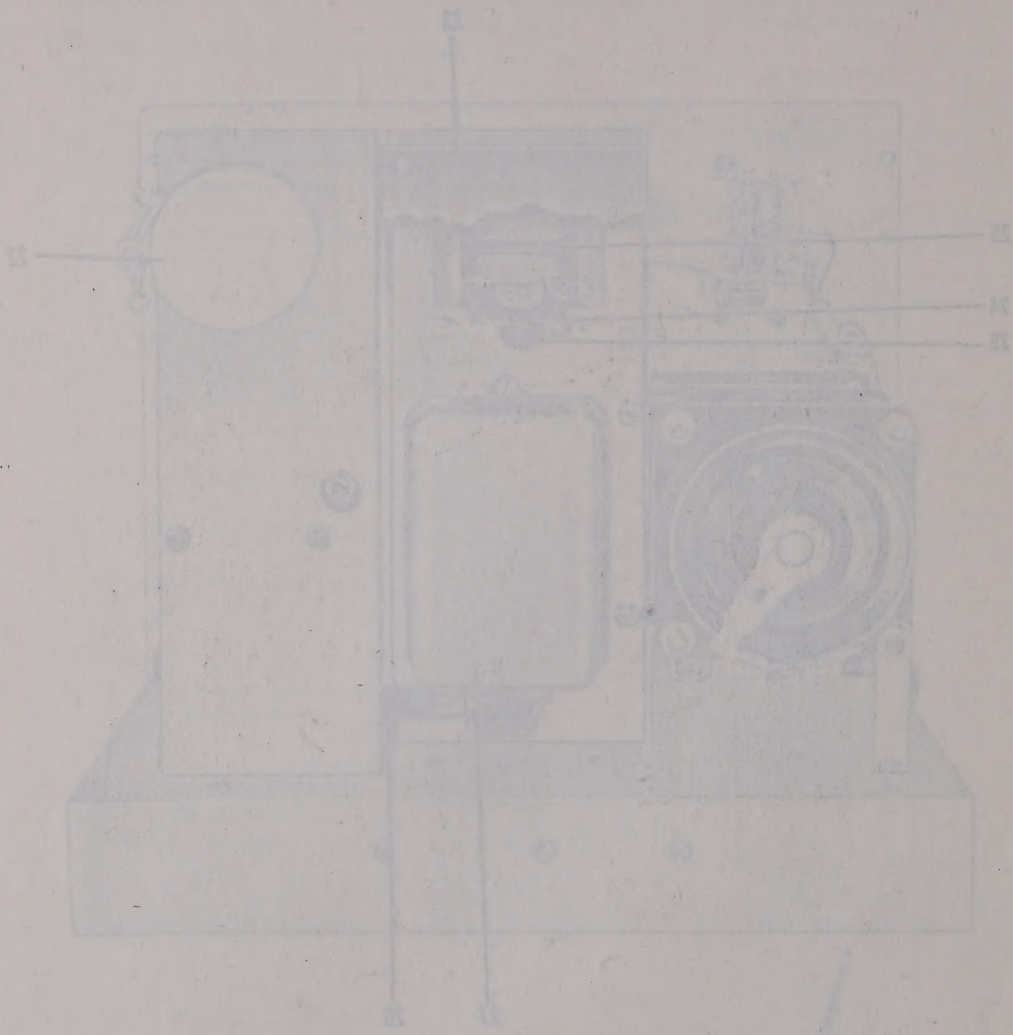


Figure 7-2. Impedance Bridge (Sheet 2 of 3)



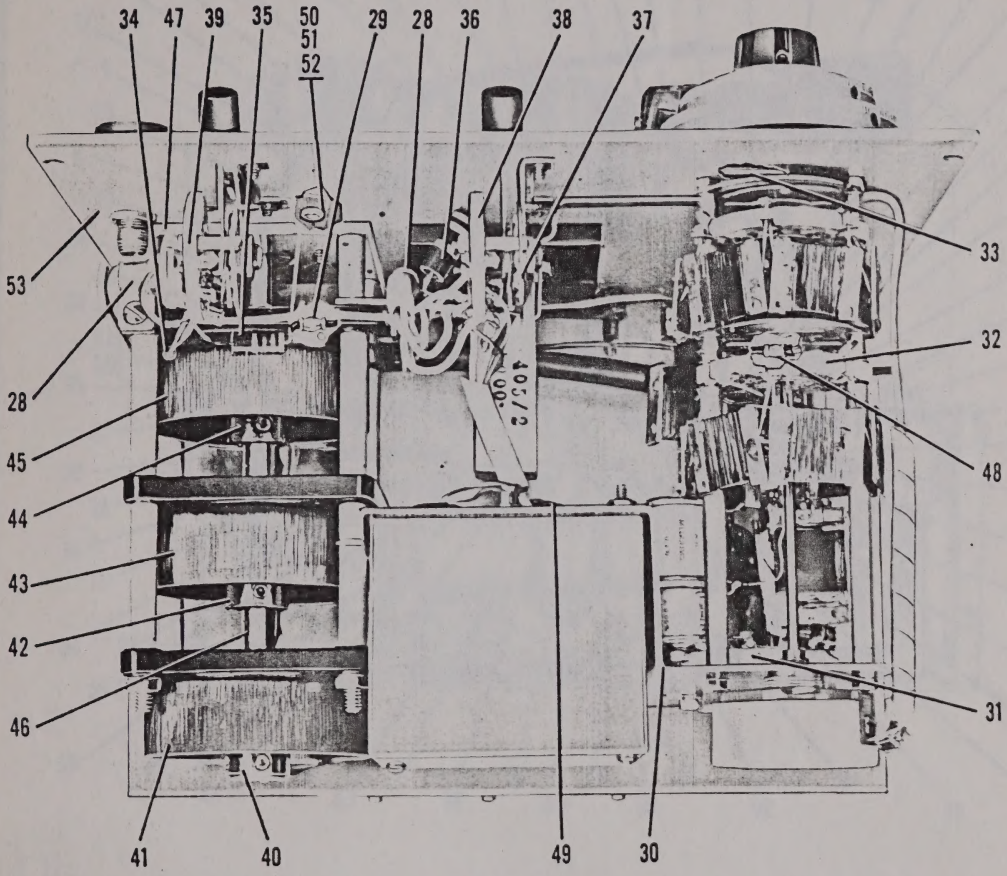
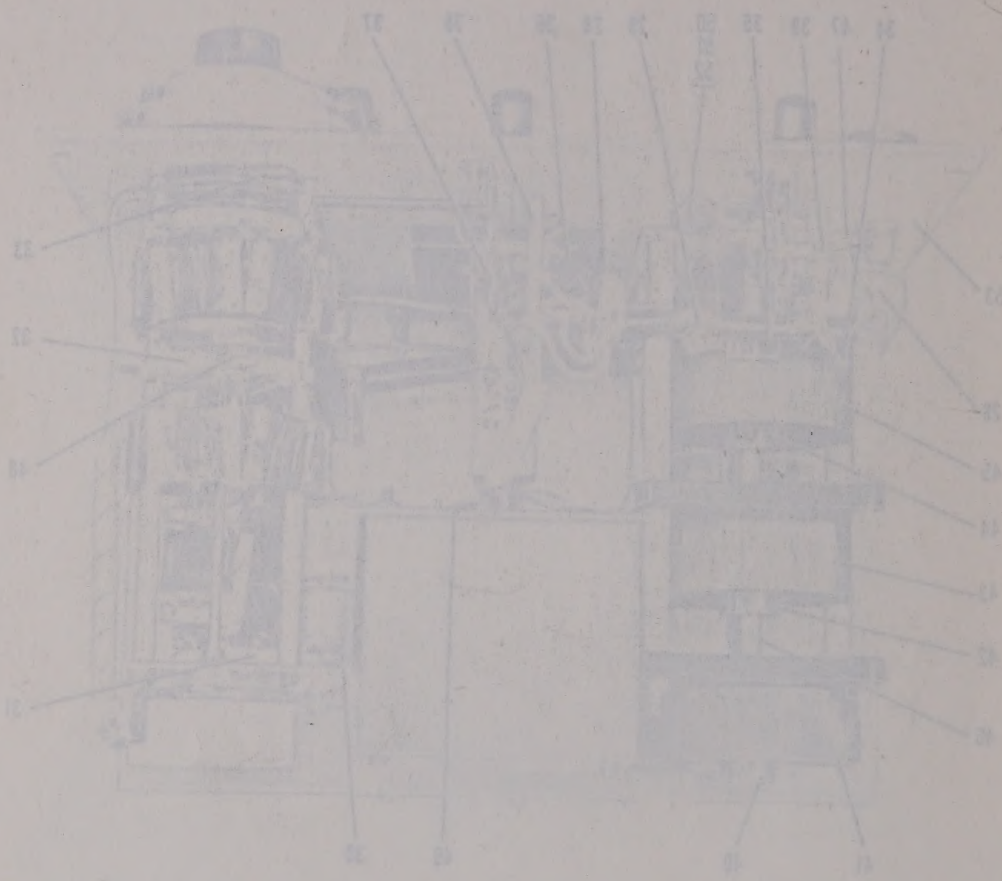


Figure 7-2. Impedance Bridge (Sheet 3 of 3)



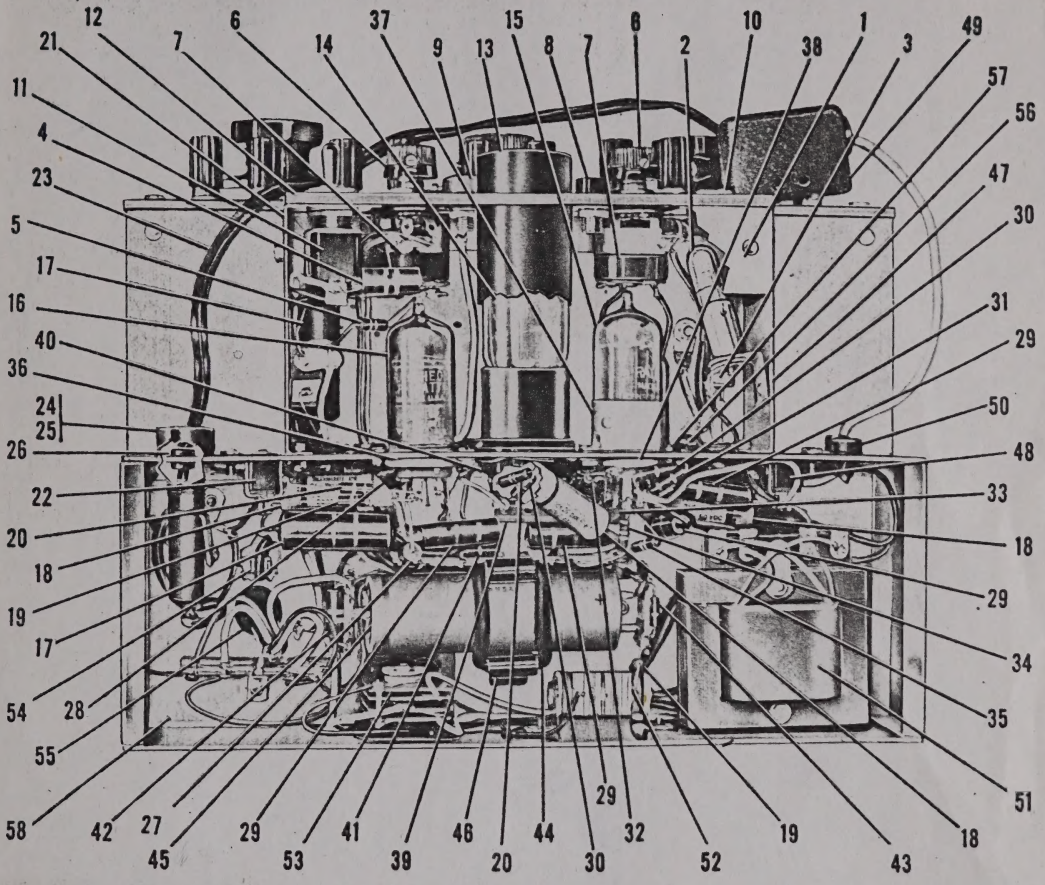


Figure 7-3. Oscillator-Amplifier Assembly